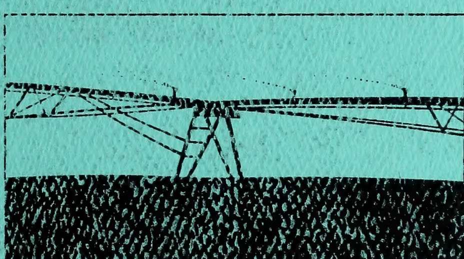
IRRIGATION AND RESOURCE MANAGEMENT DIVISION



Applied Research Report 1989-90 1990-91

Alberta
AGRICULTURE

PREFACE

This publication consists of reports prepared by staff involved in applied research from the Irrigation and Resource Management Division, Alberta Agriculture. Summary and progress reports on completed and ongoing research and demonstration projects for the 1989-90 and 1990-91 fiscal years are presented. The reports are limited in length for brevity. More detailed reports are available from the authors.

Reports have been grouped into one of seven sections according to the major emphasis of the subject matter. Papers are presented as they have been received from the author(s), with no attempt to modify the content. Editing and peer review have been accomplished to varying degrees for each of the reports submitted.

Also included in this report are several summary reports on research conducted by Dr. R. C. McKenzie, Research Agronomist, Alberta Special Crops and Horticultural Research Center in Brooks. These reports are of interest to those involved in irrigated and dryland agriculture in Alberta.

This publication is intended for use by people involved in agricultural extension, particularly those dealing directly with farmers.

L. B. SPIESS, Editor

Brian Colgan, Director
Irrigation and Resource Management Division

ACKNOWLEDGEMENTS

Projects reported within this publication have been carried out with the assistance of many individuals and organizations. Gratitude is expressed to all technical, professional and administrative staff who have contributed to the planning, implementation and completion of each of these projects. Assistance from the Drafting Unit and the Soil and Water Laboratory in Edmonton, are particularly appreciated. The efforts of Mr. R. T. Heywood in co-ordinating the assembling of this report is noted and greatly appreciated.

Funding obtained for several of these projects was obtained through the Farming for the Future Program and from the Alberta Heritage Savings Trust Fund, Irrigation Rehabilitation and Expansion Research Program. This assistance is gratefully acknowledged.

A special thank you is extended to the many farmers that allowed access to their land for sampling and monitoring associated with these applied research studies.

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DEFLECTIONS IN PLASTIC IRRIGATION PIPELINES

S. Jonas[1], J. Stewart[2]

INTRODUCTION

The purpose of this study is to determine the conditions of selected plastic irrigation pipelines.

BACKGROUND AND METHODOLOGY

The study was initiated in response to reports of reduced capacity in some irrigation pipelines. Alberta Agriculture began their inspection program in 1981.

Early examinations were conducted by towing a video camera through pipelines (via a rope that was previously floated through the pipe during irrigation season) to obtain pictures of the pipe interior. A signal was relayed by video cable to allow viewing on a television monitor, and a video tape was made to record the information received. The results portrayed defects such as: separated joints, displaced gaskets, presence of debris and deformed pipe.

In 1983 a decision was made to study pipeline deformation more intensively. An engineering firm (Emku Engineering) was hired to develop equipment that would electronically measure pipeline roundness in four different axis. The prototype "deflectometer" consisted of four pairs of opposing flexible arms. A signal, generated by pipe deflection, is transmitted through strain gauges on each arm, amplified and sent through an electrical cord to a strip chart recorder located in the service vehicle. A Canon Snappy 20 camera, with remote trigger, was towed behind the deflectometer in a waterproof sleigh so any large deflections could be recorded visually.

By 1986 modifications to the deflectometer had increased its data gathering accuracy and expanded its inspection capabilities to underwater conditions. A datalogger mounted on the deflectometer sled replaces the old system of transmitting readings through an electrical cord to a remote strip chart recorder. A distance measuring wheel mounted on the deflectometer sled triggers the datalogger to record strain gauge readings at one meter intervals. A power winch with constant towing speed has replaced the 4x4 truck that was once used to pull the deflectometer through the pipe.

RESULTS AND DISCUSSION

On the average, pipeline showed an elliptical shape resulting from horizontal compression and vertical expansion. This would indicate possible under compaction at the haunches of the pipe and possible over compaction from above.

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The worst pipeline examined in a 560 mm diameter polythylene pipe registered average deflections of 11% in both horizontal and vertical directions. On the other side of the scale the best pipeline a 600 mm diameter permaloc exhibited an average of 3.7% vertical and 1.8% horizontal deflections. Permaloc is PVC pipe constructed with outside rib support.

Deflectometer accuracy, portability and ease of operation have been increased by use of the datalogger. The redesign of the distance measuring wheel and electronic sensor used to trigger the one meter readings has also improved the accuracy and ease of operation of the instrument.

The pipeline deflection study was completed in the spring of 1990. Field data is presently being compiled and a comprehensive report is being prepared.

CONCLUSIONS

The deflectometer pipeline inspection system is producing accurate results. It has effectively replaced the video inspection method which produced results based on visual interpretation only. It is proving to be a viable means to accurately determine if pipeline deflection is within the allowable limits as specified in contract documents.

The deflectometer will both check the condition of newly installed pipelines before a contractor's work is accepted and inspect older pipelines for deterioration and damage.

ELIMINATION OF AQUATIC WEEDS IN IRRIGATION CANALS USING TRIPLOID GRASS CARP

S. Jonas[1], D. Lloyd[2]

BACKGROUND

An extensive five year research study has been initiated to evaluate the impact of sterile triploid grass carp (Ctenopharyngodon idella) on controlling undesirable submersed rooted aquatic vegetation in canal systems in Alberta. Plant eating fish have been used to control aquatic vegetation for many years in Europe and Asia. Grass carp were originally introduced into the United States in 1963 and now can be found in 40 states. Triploid grass carp have not previously been used in Canada for aquatic vegetative management.

The present five year research plan initiated by Alberta Agriculture in co-operation with Alberta Forestry, Lands and Wildlife, Alberta Environment, Alberta Irrigation Projects Association and Agriculture Canada is a first for Alberta and probably Canada. The Committee on Biological Control of Aquatic Vegetation was formed to oversee this research and has representation from each of the above agencies. Funding for this research project has been approved by Irrigation Council of Alberta from the Alberta Heritage Savings Trust Fund - Irrigation Rehabilitation and Expansion Research Program.

In year one of the study (1988-89) approximately 5000 larval grass carp were acquired from Lee County Hyacinth Control District, Fort Meyers, Florida (Dr. John Cassani). The fish were held under quarantine conditions at the Alberta Environmental Centre and grew to an average fork length of 10.3 cm and weight of 21 g by March 31, 1989. Ten component task studies were undertaken by this committee.

RESEARCH METHODS

In year two of the study (1989-90) work has continued on the ten tasks as outlined in our five year research plan. Each technical component is managed by a professional(s) as named in the co-operative study.

<u>Construction of Fish Barrier (Jonas)</u>

A prototype vertical steel bar fish barrier was design and constructed at the upstream end of the Raymond Main Canal test section in an effort to test its effectiveness. The barrier will be utilized in year three of the study to keep large predator fish out of the study area and contain triploid grass carp. A smaller wooden and steel structure was installed on the downstream end of the test section. When the canal was primed with water in early spring, the small bar screen became clogged with debris and despite repeated cleaning efforts, the screen had to be removed before flooding occurred.

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First year results indicate a need to further refine the large upstream fish barrier. Instead of the vertical bar structure, an inclined horizontal bar screen with 25 mm spacing between bars will be in place for the 1990 irrigation season. It is anticipated that this structure will pass floating aquatic weeds better than a vertical bar structure.

Collection & Transportation of Fish (Bidgood & Bishop)

In May and June of 1989 approximately 1000 grass carp were transported from the Alberta Environment Centre in Vegreville to raise in five shallow aquatic weed infested dugouts and one deep holding dugout. The fish were transported in two 840 litre aluminum tanks, each tank was equipped with two graphite air stones and a pressure bottle of oxygen. These tanks performed very well. No stress was apparent in the fish, and there were no mortalities incurred from any of the four seven hour trips. In the fall, after the water temperatures had dropped below 10 degrees Celsius in the dugouts, the fish were captured and transported into deep oxygen rich dugouts to overwinter. Various methods for recapturing the fish were tried but more development work will be necessary to refine equipment and methodology.

Plant Biomass Studies (Burland & Allan)

Canal: In 1989, the aquatic plant biomass studies continued at the Raymond Main Canal study site. Seasonal aquatic standing crop measurements during the growing season have shown that early aquatic weed growth was predominantly stonewart (Chara valgaris) in May followed by Richardson's and sago pondweeds (Potamogeton richardsonii and Potamogeton pectinatus) in June. July's growth was predominantly sago pondweed while August's growth was the reappearance of stonewart along with Sago and Richardson's pondweed. A moderate amount of narrow leaf plantain (Alisma gramineum) and leafy pondweed (Potamogeton foliosus) was also present.

Using snorkelling gear, fresh weight crop samples from seven sampling sites along the 4.8 km stretch of this irrigation canal were harvested during the irrigation season.

The second growth of stonewart contained more dry matter (22 to 30 percent) than early spring stonewart (10 to 18 percent). This higher late fall dry matter content sustains the triploid grass carp in the canal until low water temperatures cause the fish to cease feeding.

For the Raymond Irrigation District Main Canal the seasonal fresh weight standing crop would appear to range from 0.15 in early June to 2.99 kg/m^2 in mid August (1,500 to 29,900 kg per hectare) or 1,500 to 4,000 kg/ha dry weight matter per irrigation season.

Dugouts: Aquatic plant biomass in the six stocked dugouts was not sampled because of lack of availability of certified scuba divers and the problems associated with working in total blackness once the sediments became disturbed. Weed growth was visually assessed by snorkelling and surface observations on four occasions during the summer. Aquatic weed growth in the dugouts was delayed somewhat in 1989 due to cool, wet weather in May and June.

The effect of the triploid grass carp on aquatic weed growth was slow to become apparent. This may reflect on adaptive response following captivity and rearing on non-vegetative matter.

The stocking rate at the Wilson dugout (112 kg/ha) was sufficient to cause elimination of most macrophytic growth (sago and leafy pondweed). Chara, which is an alga species, remained as a mat on the dugout bottom. The few milfoil plants that existed did not appear to be eaten. The lower stocking rates at the other dugouts appeared to result in a moderate reduction of aquatic plant growth.

Stocking Rates & Growth Measurements of Fish in Dugouts (Bidgood & Bishop

Feeding: Initially the five shallow dugouts were supplied with supplemental feed (catfish pellets and lawn clippings) until sufficient weed growth had occurred, at which time the supplemental feeding was stopped and the fish allowed to forage. Plontke #1 dugout, which was constructed in the fall of 1988, did not have any significant aquatic weed growth, and therefore supplemental feeding (catfish pellets and lawn clippings) continued throughout the growing season. Since triploid grass carp cease feeding when water temperatures near 10 degree Celsius all supplemental feeding was stopped when water temperatures approached this value.

Survival & Growth: Sample netting for length and weight was conducted at various times throughout the growing season. The survival rate from May through September in the Plontke #2 and #3, Wilson and Jail dugouts was 82%.

A problem was encountered in the Duff dugout, where only 3 of 211 fish stocked survived. It is unknown how this occurred, however, several possibilities exist, i.e. fish eating birds or mammals, disease, suffocation, chemical poisoning, escape or theft. Since this is a highbanked land locked dugout, water must be pumped or piped in - escape is virtually impossible. Theft seems remotely possible; the low percentage of recaptures of grass carp with electroshocking and netting attemps, without drawing the water level down, leaves this possibility low on the scale. The Duff dugout was visually inspected almost daily, however, no corpses were ever seen or found. Seasonal growth of the grass carp (by weight) is presented in Table 1.

Table 1. Growth, by weight, of grass carp (Ctenopharyngodon idella) stocked into 6 dugouts in southern Alberta after one growing season (May to October).

Dugout Name	Mean Weight of Fish (g) When Stocked Mean	When Harvested Mean	Mean % Gain In Weight
Plontke #1	35	112	220
Plontke #2	30	100	233
Plontke #3	30	179	496
Wilson	30	124	313
Duff	41	52	27
Jail	36	68	89

Growth rates were highest in Plontke #3 where the mean weight of the triploid grass carp population increased 496%. The triploid grass carp in the Jail Dugout showed only a modest increase in size. This may be a reflection of a stocking rate that was too high. A dugout which is initially stocked with what is thought to be an appropriate number of fish may be actually overstocked due to eventual fish growth. The Jail Dugout became denuded of vegetation towards the middle of summer, resulting in a cessation of growth for the fish, hence the lower percent weight gain. The additionally low values obtained from Plontke #2 dugout were possibly a combination of fish biomass overtaking food production and water turbidity reducing an already low food base. Plontke #1 dugout, which was supplied with supplemental feed for the duration of the growing season, showed the growth that can be expected.

Pathology Services (Moore)

Health Evaluation: Approximately 60 carp were randomly selected and submitted for diagnostic viral examination at the Hatfield Marine Sciences Centre (Oregon State University). No pathogenic viruses were detected. Histopathologic evaluation was conducted on nine fish. No lesion indicative of microbial or chemical disease was found in any tissue in all major organic systems. Triploid grass carp were also provided for bacteriology evaluation to the Fish Disease Laboratory, Animal Health Division, Alberta Agriculture in Edmonton. No pathologic bacterial agents were isolated.

Experimental Studies: A 42 day trial designed to assess growth and survival of grass carp in warm (20 degrees celsius) and cool (7 degrees celsius) water was completed. Data anlysis is currently underway.

Triploid Evaluation: Verified triploid determinations came to 381 fish. An additional 42 chromosome counts and 25 Quality Assurance & Quality Control (QA/QC) determinations were conducted. The QA/QC procedure involved the use of chromosomes from fathead minnow as positive controls. Of these carp examined, 97.9% were found to be triploid.

Co-operative Research: Diploid grass carp, from Alberta Environmental Centre, were used by the Bureau of Reclamation, U.S. Department of Interior (Denver, Colorado), for comparison of mersitic characteristics with populations in the western U.S.A.

Aquatic Weed Problem Survey (Burland)

In 1988, the irrigation districts were canvassed for information describing the extent, nature and location of aquatic weed infestations in canals. Information on physical characteristics such as structures, flow rates, widths and depth of canals was also sought. This information was used in 1989 to assist in providing operational cost/benefit analyses and to provide a basis for predicting any adverse environmental impact that may be associated with this use of the triploid grass carp.

To date, all of the irrigation districts except the Taber Irrigation District have provided the committee with the requested information. The material is now being assimilated into a format to facilitate further analysis.

Those irrigation districts that provided aquatic weed information were field checked after the 1989 operating season to verify the data. Reservoirs and canals from each district were visually inspected to determine structures, size, and weed growth. This exercise detected few discrepancies in the data submitted by the districts.

The information received from the irrigation districts has been transferred onto draft referral maps that are now awaiting further refinement and digitizing. For each irrigation district, a tabulated summary of canal/weed growth information has been produced and is on computer.

A total of 1289 kilometres of canal contains aquatic weed growth requiring control. This translates into a surface area of 1313 hectares (3308 acres). Once an area value for all irrigation districts is derived, it will be factored with the recommended fish stocking rate to determine the amount of triploid grass carp required for an overall control program.

Water Quality Studies (Allan):

Duplicate water samples were taken during 1989 from all dugouts and irrigation canals that contain or that might contain the grass carp. The samples were returned to the Lethbridge Agriculture Centre where they were processed to determine 24 water quality parameters.

The dugout water was of excellent quality for the maintenance of triploid grass carp except for three which had very high (200 mg/L) sulphate levels. These three dugouts were not stocked with fish. The total solids and total dissolved solid fractions remained fairly steady during the growing season with no suggestion of increases due to the stocking of fish. There were no increases in nitrogen (nitrate, nitrite or ammonium) compounds during the season. There were no significant changes in the nutrient levels but the water clarity was very good and there was no evidence of blue-green algae blooms. This last point could be very significant if it persists in the years to come.

The water quality of the Raymond Main Canal is good for the maintenance of triploid grass carp and remained stable all season. The only significant change was an increase in nitrates in August and this was accompanied by increased aquatic weed growth in the late season. Filamentous algae increased moderately in late August but was not a problem in the 1989 season. Silt loading remained low all season. On the basis of water quality and aquatic vegetation seasonal biomass, this canal should be a good test site for stocking the triploid grass carp. The inner banks of the irrigation canal are generally heavily grassed which prevents nutrient enrichment from surface runoff and should offer some shelter for the stocked fish.

Predacious Fish Study (Jonas):

The predacious fish surveys were conducted in the fall after the Raymond Main Canal had been shut down for the season. The 1989 objective was to determine the quantity and size of predacious fish (northern pike, walleye, and sauger) present in the two proposed test reaches of the Raymond Main Canal.

The predacious fish were recovered after pumping out the remaining low lying pools of water. Predacious fish recovered were smaller in size and fewer in number than those taken in the 1988 survey. This was expected due to the installation of the fish barrier which did not allow the movement of larger fish from Corner Lake into the test reaches.

One additional reason for finding fewer fish in the 1989 survey may be because of the fish removal in the 1988 survey. Had these fish not been removed they may have overwintered in the pools and been captured again in the 1989 survey. From previous research studies (not related to the carp studies) it is possible for northern pike to survive in a canal through a winter in a pool of water 600 mm deep.

The fish barrifish - no northern pike larger than 300 to 400 mm (fork length) were found in pools below the structure.

Overwintering (Jonas):

Approximately 970 triploid grass carp are being "overwintered" in the deep oxygen rich dugouts. These holding dugouts were selected because of their continually high dissolved oxygen readings after monitoring them throughout the 1988 winter. Automated recording stations were assembled on three of the dugouts. These systems continuously record dissolved oxygen, air and water temperatures along with the time and date. Dissolved oxygen readings are manually taken once a week on all of the winter dugouts. Ice thickness and snow cover are also measured on a weekly basis.

Report Preparation (Lloyd):

A year I executive summary report was published and submitted to Irrigation Council and other interested groups.

CONCLUSIONS

All major aspects of the research study (Year II) were successfully implemented.

Triploid grass carp were highly effective in the removal of rooted aquatic weeds from dugouts in southern Alberta.

Despite exhaustive study, no pathologic or other microbiological agent has been found in the triploid grass carp used in the study.

Mortality of grass carp has been generally low.

Further refinement of fish barrier is required to reduce clogging and passage of 300 mm (fork length) northern pike.

None of the water in the stocked dugouts became muddy or developed phytoplankton blooms as a result of the feeding activities of the triploid grass carp.

An important factor in determining the degree to which aquatic weeds will be controlled in cool water is determining a triploid grass carp stocking rate for this area.

RECOMMENDATIONS

The Committee on Biological Control of Aquatic Vegetation recommends that, based on Year II results, the study proceeds as originally outlined and a small trial stocking of triploid grass carp be initiated in two 1 km reaches of the Raymond Canal.

Committee for Biological Control of Aquatic Vegetation members are:

D. Lloyd, Chairman	Alberta Agriculture
S. Jonas	Alberta Agriculture
J. Allan	Agriculture Canada
B. Bidgood	Department of Fish and Wildlife
F. Bishop	Department of Fish and Wildlife
R. Burland	Alberta Environment
J. Moore	Alberta Environment
B. Wilde	Alta. Irrigation Projects Association
G. Chalmers	Alberta Agriculture
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IRRIGATION SUITABILITY OF SOLONETZIC SOIL ASSOCIATIONS IN EAST-CENTRAL ALBERTA

D.R. Bennett, T.M. Peters and P.D. Lund[1]

INTRODUCTION

The objectives of this new Farming for the Future study in the Berry Creek Basin of east-central Alberta are:

1. To determine the forage production capability of a number of different Chernozemic and Solonetzic soil associations under three levels of irrigation.
2. To assess changes in soil salinity and sodicity in these soils as a result of the three different levels of irrigation.
3. To evaluate the irrigation suitability of several different soil types in light of the irrigation management regimes implemented.

METHODS

Four study sites in the Berry Creek Basin of east-central Alberta were selected for this project in the summer of 1990 (Fig. 1). Each study site was comprised of a rectangular field with dimensions of approximately 55 m wide by 340 m long. Each field is to be broken from native pasture in the spring of 1991 and four treatments, representing three levels of irrigation - 200, 300 and 400 mm, and a dryland control - will be replicated three times within each study site (Fig. 2). Barley will be used as a nurse crop for establishment of alfalfa during the first year of cropping (1991) and alfalfa will be grown under the irrigation treatments for another three years. A solid set irrigation system will be installed at each plot location and water will be applied in five irrigation events for each treatment. Soils will be characterized in detail and sampled in the fall of 1990 and again each fall from 1991 to 1994. Crop yield will be determined by sampling crops at the ten locations within each plot where soils were sampled. Mean values from each plot for soil chemical and crop yield parameters will be analyzed each year using a split-plot analysis of variance statistical model.

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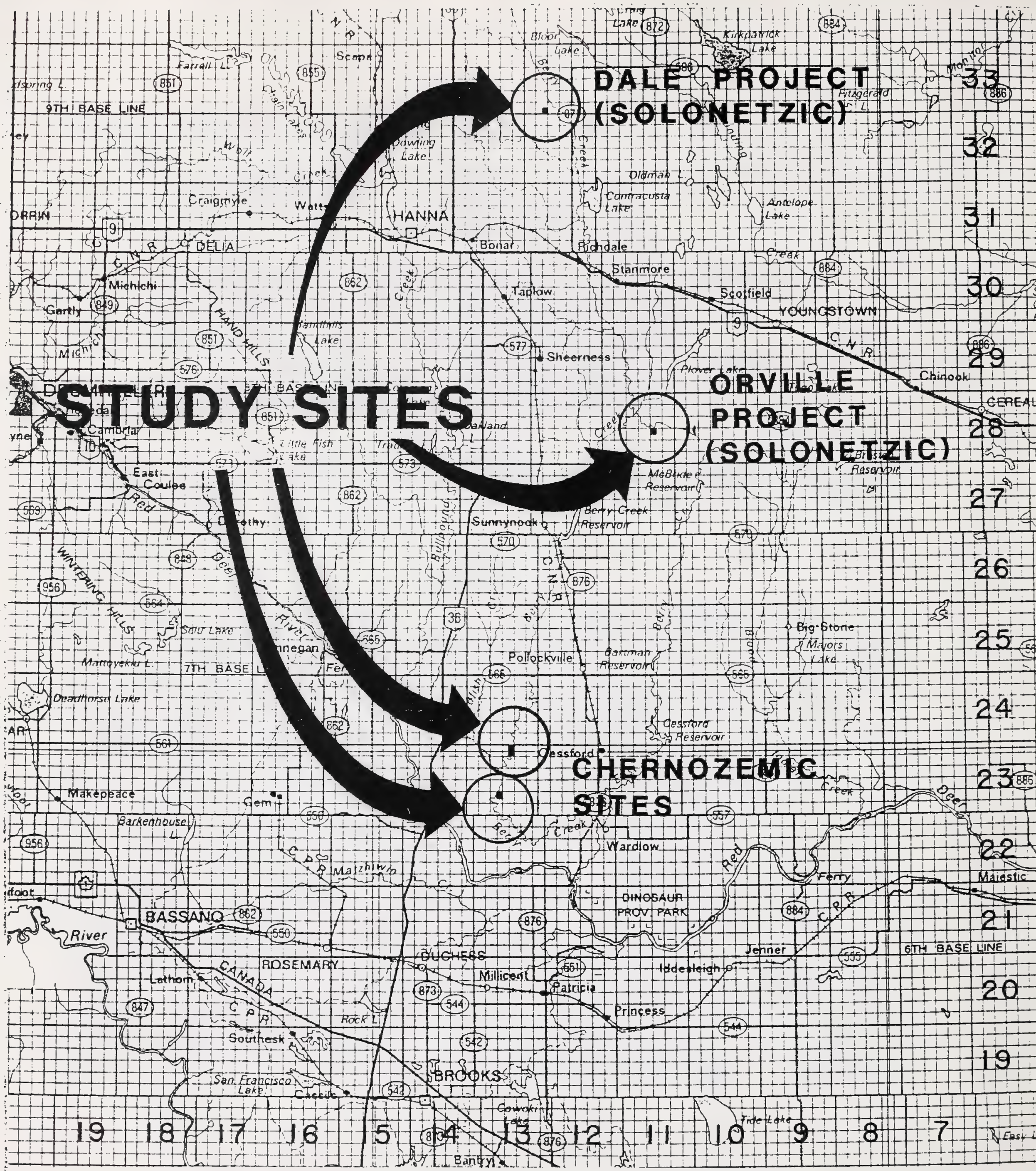

Figure 1. Location of study sites in the Berry Creek Basin.

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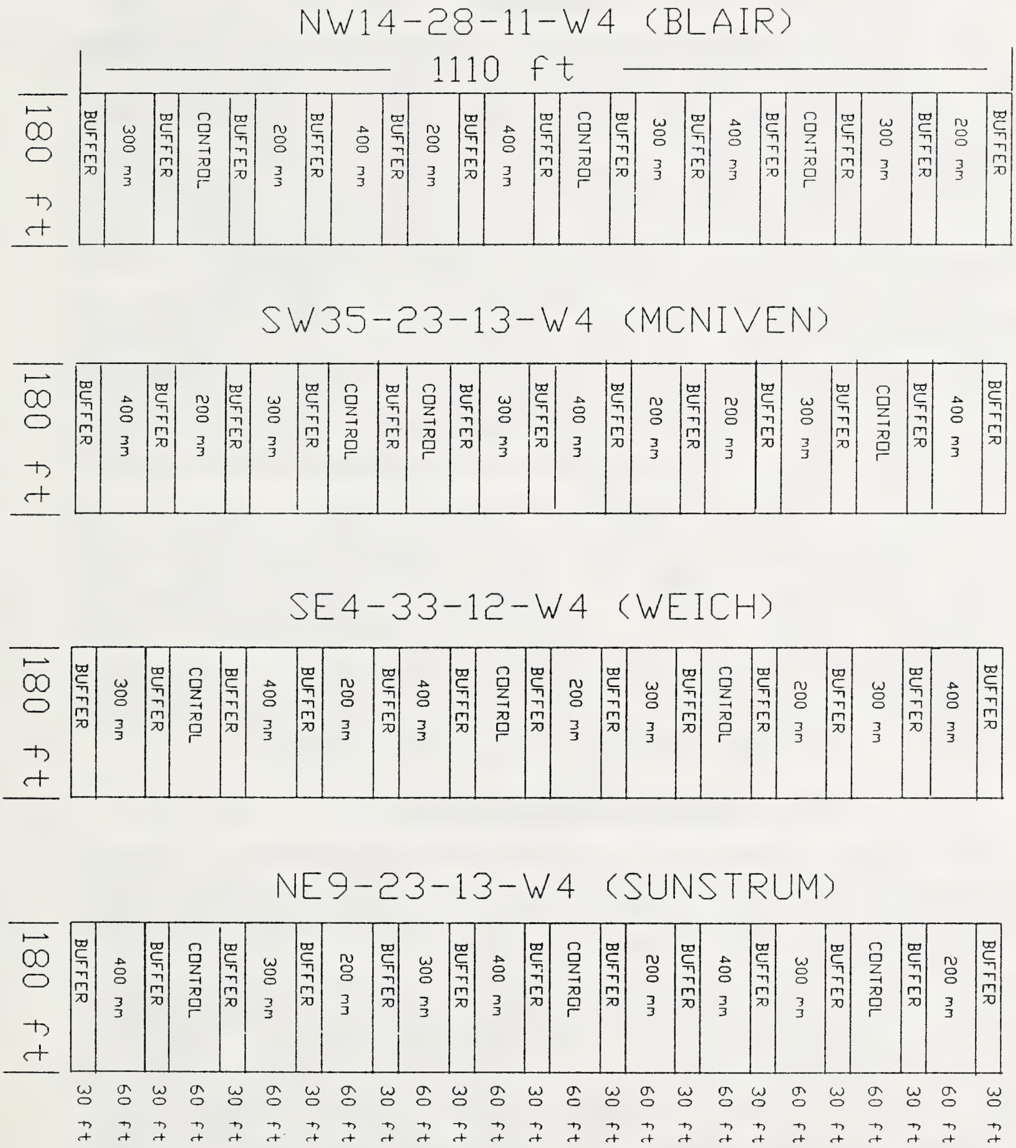

Fig. 2. Location of treatments at each study site in the Berry Creek Basin.

SUBSURFACE DRAIN EFFLUENT MONITORING

K.M. Riddell[1]

INTRODUCTION

As of 1985, there are approximately 270 subsurface drainage systems installed within the irrigation districts of southern Alberta (Harker and Mikalson 1986). The drainage systems are used to control water table levels in saline/waterlogged areas affected by canal seepage and/or natural groundwater discharge. Over 90% of these subsurface drainage systems have gravity, free-flow outlets (Harker and Mikalson 1986). Effluent from these outlets is discharged into a variety of disposal sources including natural drains (32%); constructed drains (21%); irrigation canals (19%); dugouts and sloughs (6%); road ditches (4%) and rivers and streams (2%). Effluent discharging from subsurface drainage systems has the potential to impact on surface water quality.

For example, selenium toxicity has been encountered in the San Joaquin Valley region of California as a result of subsurface drainage effluent being discharged into surface waters (Albasel et al. 1989). Salt loading from subsurface drain effluent into surface waters is a problem which has received considerable attention in irrigated areas of the Western United States (Oster and Rhoades 1975). Monitoring of subsurface drain effluent from irrigated potato fields in New Brunswick revealed levels of nitrates which often exceeded the 10 ℓ limit considered safe for drinking water (Milburn et al. 1990).

Alberta Agriculture began monitoring the quality and quantity of drainage effluent in 1978 to assess its potential impact on surface water quality. Salinity and nitrate levels were monitored on a routine basis, while trace element and pesticide levels were monitored on single samplings. Monitoring continued until 1984 and the database developed was used to predict present and future impacts of drainage effluent on surface water quality in receiving streams (Harker 1983).

In 1990 drain effluent monitoring was re-initiated. The objectives were to update the data base on flow and the amount of salts, nitrates and trace elements in drain effluent and to examine trends indicating long-term changes in the quality and quantity of drain effluent.

MATERIALS AND METHODS

Water quality samples and flow measurements were taken on a monthly basis at approximately 43 subsurface drain outlets in the irrigated portion of southern Alberta. Samples were collected from May to November. All sites had been previously sampled on a monthly basis, for varying lengths of time, between 1978 and 1984.

Samples were collected in Nalgene sample bottles, kept on ice in insulated coolers and refrigerated prior to analysis. Routine cations, anions, nitrates and electrical conductivity (EC) were determined on all samples according to standard methods for water analysis. Laboratory analyses were done either one or two days after sampling. Separate samples for trace metal analyses were collected during the May, August and November samplings. The trace elements analyzed for were manganese (Mn), iron (Fe), molybdenum (Mo), cadmium (Cd), lead (Pb), arsenic (As), selenium (Se) and mercury (Hg). All trace metals were determined using atomic adsorption methods.

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RESULTS AND DISCUSSION

Comparison of historic (1977-1984) to recent (1989-90) salinity, flow and nitrate levels in drain effluent reveal very similar patterns (Figure 1). The distributions for the nitrate and flow data are highly skewed with over 80% of the samples having less than 20 mg/ℓ nitrate concentration and less than 2 ℓ/s in flow. The salinity data is also skewed towards lower values but to a much lesser extent.

The median salinity level in the 1989/90 period (6.3 dS/m) is slightly higher than the historic level (4.4 dS/m) and could possibly be attributed to the slightly lower median flow observed in recent (0.16 ℓ/s) versus historic (0.23 ℓ/s) data. The lower median flow in the recent data is attributed to lower May to September precipitation during 1989/90. May to September precipitation at the Lethbridge Research Station in 1990 totalled 187 mm whereas average May to September precipitation between 1977 and 1984 was 250 mm. It is also possible that the absence of flows from flood irrigated research plots contributed to the lower median flow.

Comparison of the percentage of monitored outlets flowing in the May to November period between recent and historic data reveals a sharp reduction in 1990 during the months of July, August, and September (Figure 2). In 1990, July, August and September (32.6, 35.9, and 6.0 mm, respectively) precipitation levels at the Lethbridge Research Station were all below the 88-year, long-term averages for these three months (41.6, 41.9 and 41.5 mm, respectively).

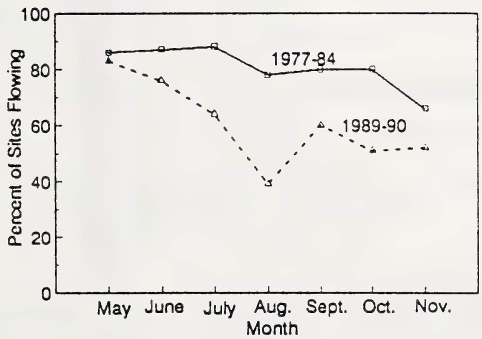
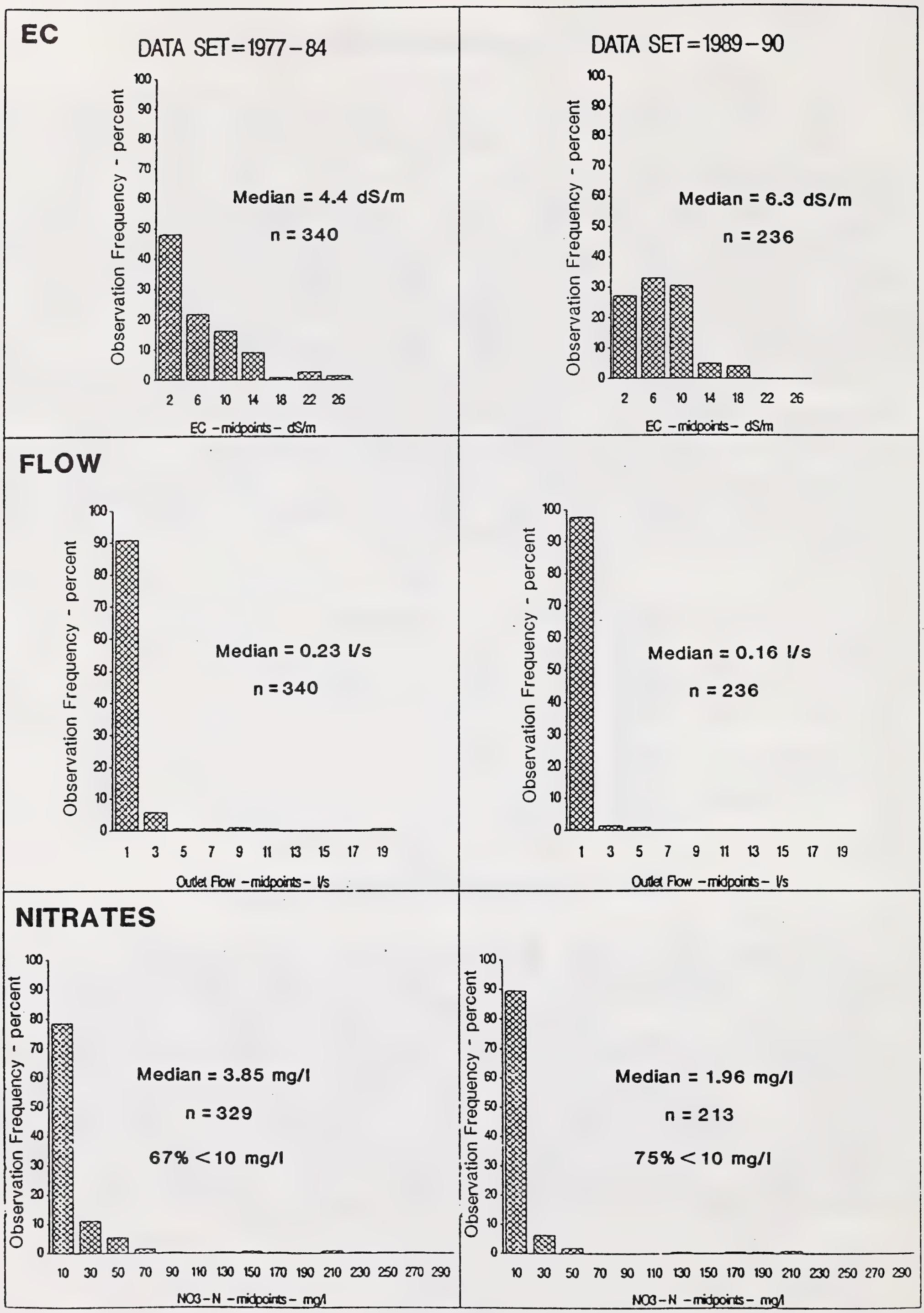


Figure 2. Percent of monitored drain outlets flowing from May to Nov. for recent (1989-90) and historic (1977-1984) data

Comparison of the distribution of nitrate concentrations between historic (1977-1984) and recent (1989-90) data sets reveals a slight decrease in the occurrence of values greater than 20 mg/ℓ in the 1989-90 data (Figure 1). Twenty-five and thirty percent of all drain outlet samples in the recent and historic data sets, respectively, exceeded the recommended limit of 10 mg/ℓ for nitrate in drinking water. The fluctuation of nitrate levels at an individual subsurface drainage outlet follows a seasonal trend (Figure 3). Nitrate levels tend to be lowest after springmelt and increase over the summer and fall. There is no apparent relationship between nitrate levels and flow at this site (Figure 3). Flow and salinity levels from an individual subsurface drainage outlet reveal cyclical cycles with no long-term tendency towards higher or lower salinity or flow levels (Figure 3).

Results of trace element analyses on 21 drain effluent samples taken in May reveal very low concentrations (Table 1). All concentrations are below Canadian Water Quality Guidelines for drinking water, aquatic life, livestock, and irrigation water (Table 1), except a single manganese value of 0.09 mg/ℓ which exceeds recommended limits for drinking water (0.05 mg/ℓ) and aquatic life (0.02 mg/ℓ).



EC
DATA SET=1977-84
Median = 4.4 dS/m
n = 340
Observation Frequency - percent
EC -midpoints- dS/m
DATA SET=1989-90
Median = 6.3 dS/m
n = 236
FLOW
Median = 0.23 l/s
n = 340
Outlet Flow -midpoints- l/s
Median = 0.16 l/s
n = 236
NITRATES
Median = 3.85 mg/l
n = 329
67% < 10 mg/l
NO3-N -midpoints- mg/l
Median = 1.96 mg/l
n = 213
75% < 10 mg/l

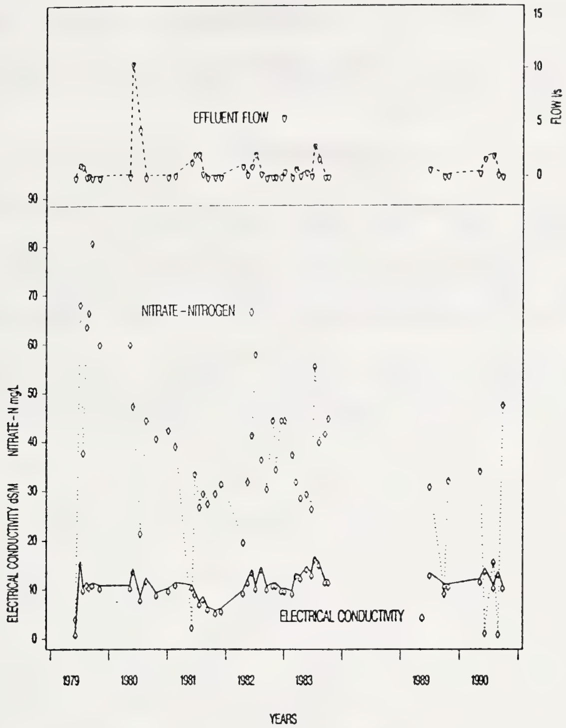


Figure 3. Monthly fluctuations in flow (ℓ/s), nitrate concentrations (mg/ℓ) and electrical conductivity (dS/m) at a representative subsurface drainage outlet.

Table 1. Concentration range of trace elements found in 21 drain effluent samples collected in May, 1990 and recommended maximum limits for drinking water, aquatic life, livestock and irrigation.

Elements	Concentration range found in drain effluent samples (mg/ℓ)	Recommended Maximum Limits (mg/ℓ) (CCREM 1987)			
		Drinking Water	Aquatic Life	Live-stock	Irrig. Water
Arsenic (As)	< 0.0003* to 0.004	0.05	0.01	0.2	0.10
Cadmium (Cd)	< 0.03*	0.005	0.0002	0.01	0.05
Iron (Fe)	< 0.10*	0.3	-----	-----	----
Lead (Pb)	< 0.03*, except for 0.03 at one site	0.05	0.03	0.05	5.0
Manganese (Mn)	< 0.03*, except for 0.03, 0.03 & 0.09	0.05	0.02	-----	0.2
Mercury (Hg)	< 0.001*	0.001	0.0002	0.003	----
Molybdenum (Mo)	< 0.10* to 0.21	0.5	-----	-----	0.01
Selenium	< 0.001*, except for 0.001 at one site	0.01	0.01	0.05	0.02

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VERDIGRIS COULEE SOIL AND WATER QUALITY MONITORING PROJECT

K. M. Riddell

INTRODUCTION

Irrigation water diverted from the major rivers of the South Saskatchewan river basin into Alberta's irrigation districts is generally of excellent quality (Alberta Environment 1982). However, there is an increasing demand for irrigation in Alberta to be developed in smaller projects outside of the established boundaries of the irrigation districts. The occurrence of marginal or poor quality irrigation water is more common in these smaller projects because water is not always taken directly from the major rivers. Common sources of marginal or poor quality irrigation water include effluent wastewater, groundwater or small quantities of water held in reservoirs susceptible to salinization from non-point salt sources such as surface runoff, bed migration, groundwater discharge, and high rates of evaporation.

The Verdigris Coulee irrigation project is an example of a small irrigation project using water which is diverted into a reservoir susceptible to salinization. Approximately 2000 hectares of land are irrigated using water from Verdigris Coulee. The quality of water used for irrigation in this project is often classified as "Possibly Safe" according to Alberta Agriculture guidelines (Alberta Agriculture 1983) because of slightly elevated salinity and sodicity levels (McMullin et al. 1984). Use of marginal quality irrigation water has caused a slight increase in soil salinity and sodicity levels (McMullin et al. 1984; UMA Engineering 1988). The impact of slight increases in soil salinity and soil sodicity on long-term soil productivity is not well understood.

In response to this need for more information, a project has been developed to monitor the quality of irrigated soils in the Verdigris Coulee irrigation project. Objectives of the monitoring program are twofold. Firstly, to provide benchmark sites for long-term monitoring of the impact of irrigation with marginal quality water on soil physiochemical properties and, secondly, to provide a database for evaluating existing water quality guidelines.

BACKGROUND INFORMATION

Irrigation of lands surrounding Verdigris Coulee in southern Alberta began in 1983 (UMA Engineering 1988). Irrigation water was made available by diverting water from the Milk River Ridge Reservoir into Verdigris Coulee through Middle Coulee (Figure 1). High quality water diverted from the Milk River Ridge Reservoir was supposed to flush existing salts from Verdigris Coulee and improve water quality throughout the length of the coulee.

Monitoring of water quality between 1983 and 1987 at the inlet and outlet ends of Verdigris Lake revealed annual and long-term fluctuations in salinity and sodicity levels (McMullin and Read 1987). Long-term electrical conductivity (EC) levels at the inlet to Verdigris Lake are stable but have demonstrated a consistent seasonal increase to levels above 1 dS/m over the winter and early spring and then a rapid decrease to levels around 0.5 dS/m with the addition of high quality water from

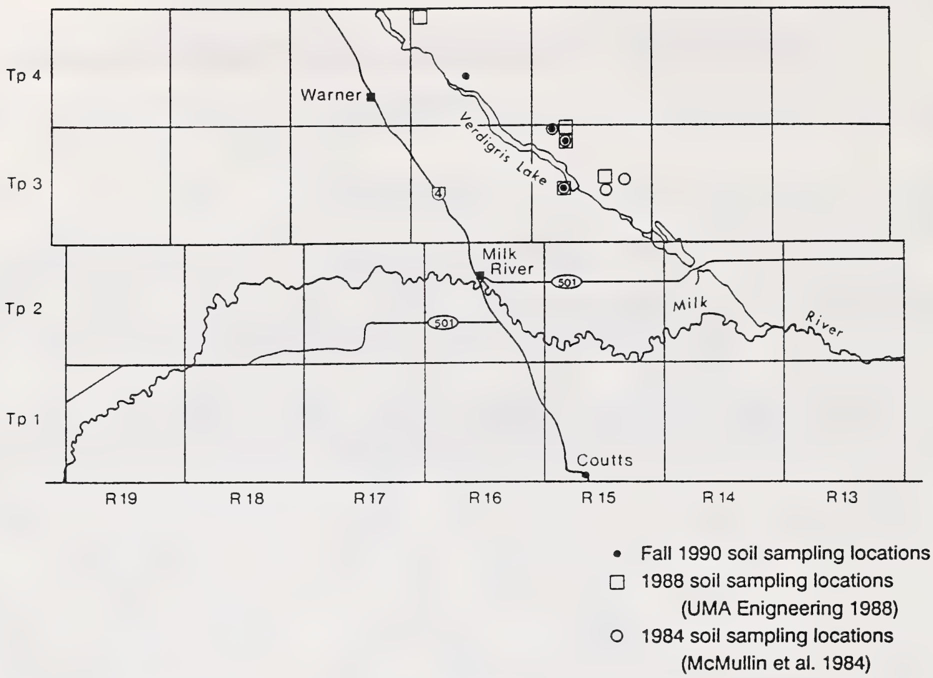

FIG. 1 Location Map for Verdigris Coulee Soil and Water Quality Study

Ridge Reservoir in May (McMullin and Read 1987). Salinity levels at the outlet of Verdigris Lake have demonstrated a long-term decline from levels of 4 to 8 dS/m in 1983 to levels of 1 to 2 dS/m in 1990 (UMA, pers. comm.). Annual fluctuations in salinity levels at the outlet end of Verdigris Lake follow a consistent trend of increasing throughout the period from April to mid-July and decreasing to spring or lower levels between August and October. The amplitude of yearly fluctuations in salinity levels of water at the outlet end of Verdigris Lake has decreased from 0.7 dS/m in 1984 (EC's ranging from 2.0 to 2.7 dS/m) to 0.2-0.3 dS/m in 1986-1987 (EC's ranging from 1.0 to 1.3 dS/M) (McMullin and Read 1987).

Explanations for the trend towards increasing salinity and sodicity levels over the winter and early spring at the inlet to Verdigris Lake include migration of salts from bed sediment (UMA Engineering 1988) and salt loading from spring runoff (McMullin and Read 1987). There is a potential for a direct and indirect contribution of salts to Verdigris Coulee from groundwater sources (Davison 1978) but this is not well documented. Long-term reductions in salinity and sodicity at the outlet end of Verdigris Lake are attributed to reduced migration of salts from bed sediments.

Monitoring of soil quality on lands being irrigated with water from Verdigris Coulee began in 1984. Comparison of soil chemical properties (EC and SAR) between adjacent irrigated and non-irrigated soils revealed elevated SAR levels in the irrigated soils (McMullin et al. 1984). A similar comparison done in 1988 also revealed increased SAR's in irrigated soils (UMA Engineering 1988). Visible evidence of short-term soil structural degradation arising from elevated SAR levels was not

seen in 1988 (UMA Engineering 1988). However, increasing concentrations of sodium in soil solution can lead to potential long-term problems with soil structure and moisture movement. Elevated SAR levels warrant continued investigation because of the potential threat to the long-term productivity of the soil resource.

METHODOLOGY

Water quality was monitored on a weekly basis during 1990 at one pump site at the outlet end of Verdigris Lake. Future water samples will be collected by all cooperating farmers. Laboratory analysis will include pH, EC, major cations and anions.

Initial soil quality sampling was undertaken in the fall of 1990 at four benchmark sites (Figure 1). Soil sampling will be done annually in the fall for the first three years and thereafter every second year. Site locations include three irrigated fields (two pivots and one wheel roll system) around the outlet end of Verdigris Lake and a pivot irrigated field at the inlet end of Verdigris Lake. Under pivot irrigation, four plots are located underneath the pivot and four plots are located in the non-irrigated corners of the field (Figure 2).

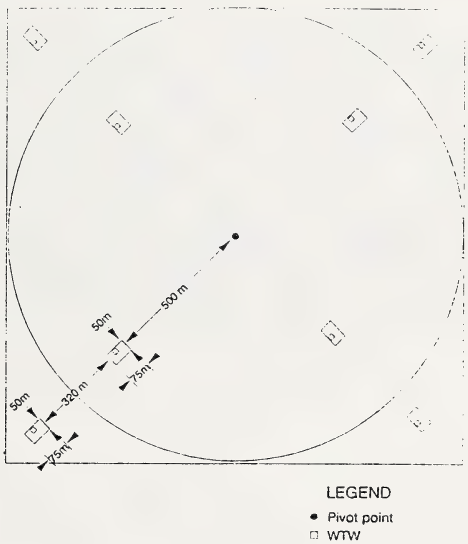

FIG. 2 Soil Sampling Plan For Verdigris Coulee Soil and Water Monitoring Study

Irrigated and non-irrigated plots are separated by a buffer zone to prevent edge effects caused by the end gun and wind drift. Under the wheel roll irrigation system, non-irrigated plots are located in adjacent fields and are separated from irrigated plots by an appropriate buffer zone.

Soil sampling to monitor changes in salinity/sodicity was conducted to a depth of 1.2 m in the following increments: 0-15, 15-30, 30-60, 60-90 and 90-120 cm. A separate 0-5 cm sample was taken at all locations and will be stored for future analysis of tilth properties. Laboratory analyses of soil samples will determine EC, pH and major cations.

Water-table wells were installed in all irrigated and non-irrigated plots in each field (Figure 2) to a depth of approximately 4.5 m. Water-table wells are being monitored on a monthly basis.

The experimental design provided will not allow for a clear comparison of irrigated to non-irrigated soil chemical properties. Differences observed between irrigated and non-irrigated soils could be attributed to differences in soil type and differences in management (irrigation, crop type, tillage, etc.). However, if for a given field, a trend develops showing a consistent difference between irrigated and non-irrigated soils at all plots, then quality of irrigation water could be strongly implicated. Also, if soil chemical properties in irrigated plots (similar soils and management) change with time and soil chemical properties in adjacent non-irrigated plots (similar soils and management) do not change with time, irrigation water quality could also be strongly implicated.

Mean comparison between years on individual plots will be done using t-tests. Comparisons between irrigated and non-irrigated plots will be limited to presenting mean values and observing trends.

RESULTS

Water quality samples collected over the summer of 1990 at the outlet end of Verdigris Lake show a trend of increasing salinity and sodicity (Figure 3). Electrical conductivity levels increased from 1.25 dS/m to 1.68 dS/m during the period between May 25 and September 11. Sodium Adsorption Ratio increased from 5.1 to 8.3 during the same period. This trend reverses the pattern of previous years where salinity and sodicity levels at the outlet end of the lake declined during August and September. Unusually low amounts of precipitation during August and September, combined with high evaporation, may be partially responsible for salinity levels increasing.

Laboratory analyses of soil samples collected in the fall of 1990 was not completed in time to be included in this report.

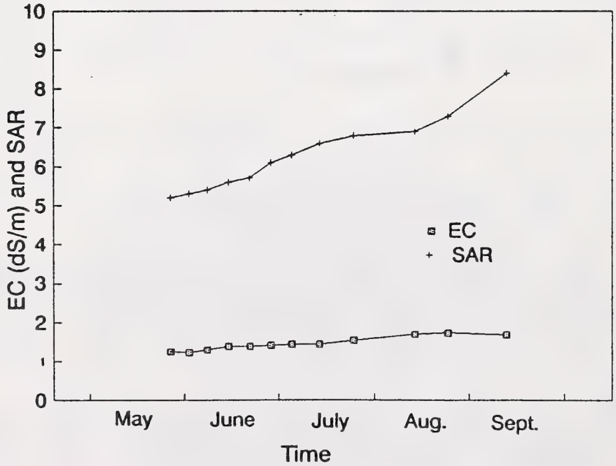

Figure 3. Electrical conductivity and sodium assorption ratio levels for water samples taken at the outlet end of Verdigris Lake during the summer of

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MIGRATION OF NITRATES TO GROUNDWATER UNDER MANURED FIELDS

Tracey Bolseng[1]

INTRODUCTION

Nitrogen is an essential element required for plant growth. A common agricultural practice is to supply organic nitrogen to the soil through the application of animal manure. This practice is common in irrigated areas of southern Alberta because large amounts of manure are produced by feedlots, which are attracted to the area by secure supplies of water and feed and the favourable climate.

Application of manure on irrigated land poses an environmental threat if the resultant nitrate (NO3-N) production exceeds crop requirements and irrigation promotes leaching of excess soil nitrate to groundwater. Nitrate concentrations in excess of 10 mg/ℓ causes potentially fatal respiratory problems in infants and lead to the production of nitrosamines, a potent carcinogen (Power et al. 1989). Nitrate levels in excess of 100 mg/ℓ also cause respiratory problems in young livestock.

A study by Chang et al. (1990) assessed the impact of long-term feedlot manure applications on the distribution of nitrate in irrigated soil profiles and groundwater. They concluded the current recommended rate for feedlot manure application on irrigated land of 60 mg/ha is too high. At this rate, nitrates accumulated in the root zone (0 - 1.5 m) during the initial years of manure application, and subsequently were leached beyond the rooting depth. This excess nitrate is a potential source of contamination for shallow groundwater.

In response to the above results, a monitoring program was initiated to determine nitrate levels in soils and shallow groundwater beneath irrigated land being used for feedlot manure disposal. The intent of the study is to document soil and groundwater nitrate levels under actual "field" conditions and provide a database which could be used to improve guidelines for manure application rates on irrigated land.

METHODS

Site selection criteria used in this study were: 1) farmer cooperation; 2) an irrigated, manured field with an adjacent irrigated, non-manured field to serve as a control; and 3) annual cereal crop grown. Five sites, representing a variety of soil types, were selected in four irrigation districts across southern Alberta.

At each site, after spring seeding was completed, four water table wells (WTW) were installed to a depth of three meters in each treatment (manured and control) field. During WTW installation, soils were sampled in 15 cm increments to a depth of 60 cm and then at 30 cm increments to 300 cm. Samples were set out to air dry within hours of sampling.

The WTW were bailed twice prior to sampling. Subsequent monitoring and sampling of the WTW was conducted biweekly until freeze-up.

Soil and water samples were analyzed for pH, EC, SAR, cations, anions and nitrate-nitrogen (NO3-N) using standard methods. The saturated soil paste extract results for NO3-N were converted to mg/ℓ on a dry soil basis.

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Table 1. Means ± standard deviations for depth weighted and total soil profile nitrate-nitrogen concentrations (mg/L) for spring 1990 Manured and Control treatments of five sites across southern Alberta[+]

Site	Depth-Weighted NO_3-N Control	Depth-Weighted NO_3-N Manured[+]	Total NO_3-N Control	Total NO_3-N Manured	Profile Depth (cm)
B	1.8 ± 0.5	25.6 ± 12.1**	27.6 ± 10.7	368.4 ± 150.7**	300
C	5.2 ± 5.0	23.1 ± 4.7**	58.2 ± 46.8	270.4 ± 62.3**	300
D	0.1 ± 0.1	9.6 ± 10.6	0.9 ± 0.7	105.9 ± 96.5	270
L	18.0 ± 12.2	8.5 ± 3.7	254.4 ± 163.2	146.5 ± 72.5	300
M	8.8 ± 4.4	18.7 ± 19.3	63.9 ± 28.1	156.0 ± 163.0	150

+ n = 4 for each site by treatment cell.

* Treatments within sites are significantly different at $p = 0.05$ as determined by an unpaired t-test.

** Treatments within sites are significantly different at $p = 0.01$ as determined by an unpaired t-test.

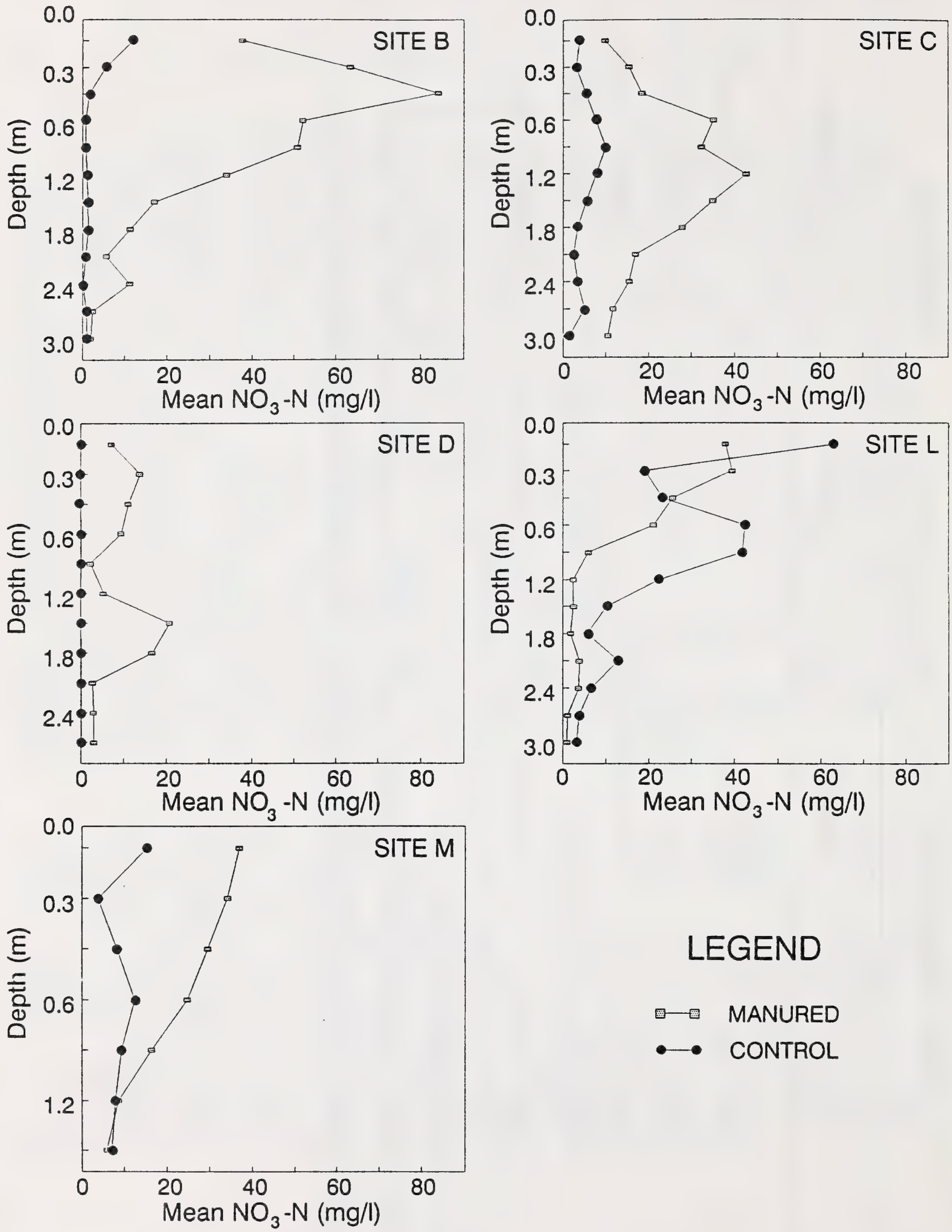

Fig 1. Mean soil NO_3-N content and distribution with depth at five locations under manured and non-manured fields.

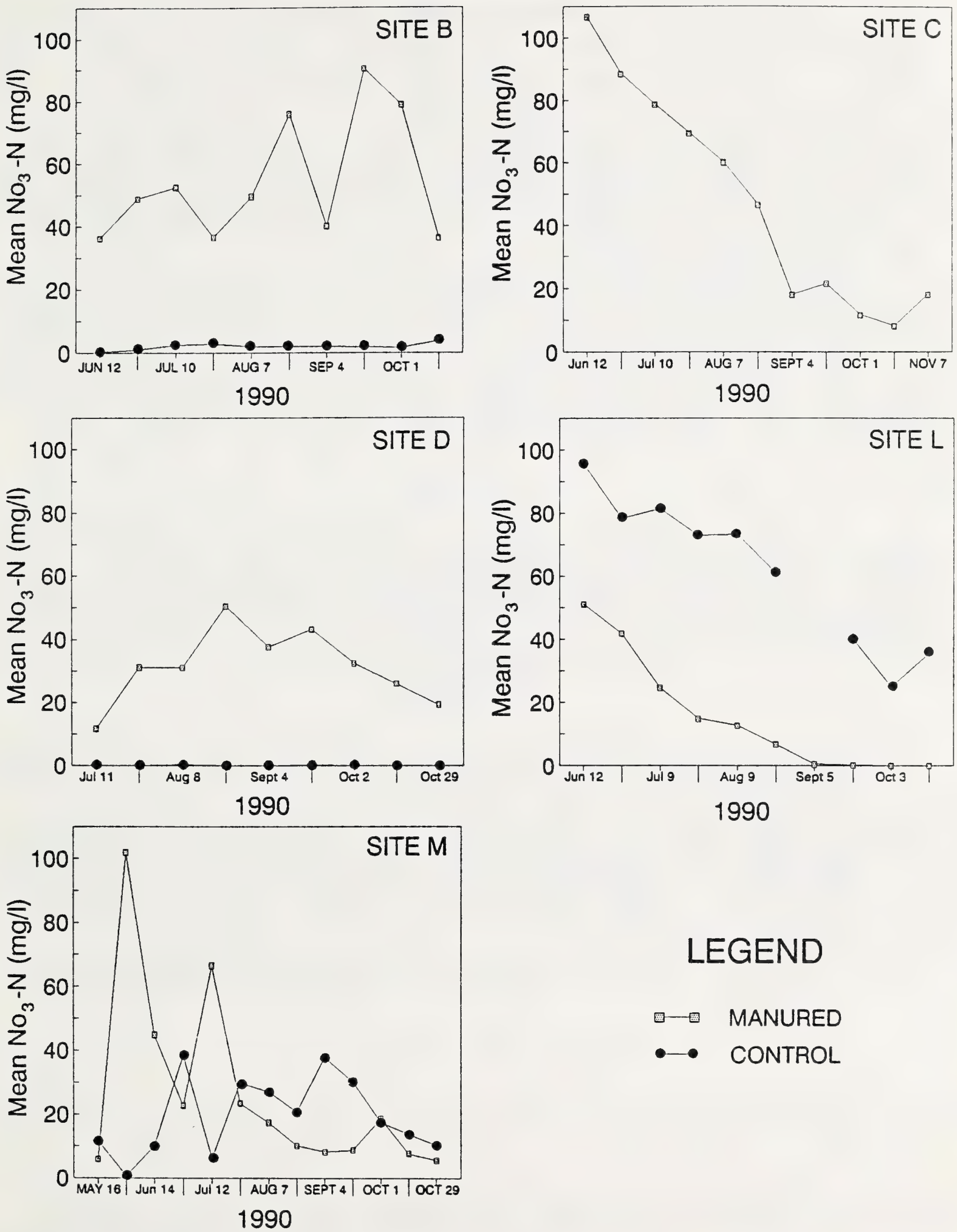

Fig 2. Mean NO_3-N concentration in shallow groundwater at five locations under control and manured fields.

RESULTS AND DISCUSSION

Mean values for both total and depth-weighted soil profile NO3-N at Sites B and C were significantly higher in the manured treatment as compared to the control (Table 1). The mean soil NO3-N content in the manured treatment of Sites B and C was substantially higher than the control treatment at all depths between 0 and 3 m (Figure 1). Soil nitrate contents at Site L were higher in the control treatment as compared to the manure treatment (Table 1). This could be due to fertilizer or cropping practices which have not been documented as yet. Manured treatments at Sites B, C and D show a NO3-N accumulation below the rooting zone for cereal crops (1.2 m) indicating that nitrate production is exceeding crop requirements and the potential for contamination of shallow groundwater exists.

The average groundwater depth at all sites ranged from 1 to 2.5 m below ground surface (data not shown). Mean NO3-N concentrations (mg/ℓ) in shallow groundwater were consistently higher under manured, as compared to control, treatments throughout the monitoring season at Sites B, C and D. The recommended maximum limit of 10 mg/ℓ NO3-N for human consumption of water (Canadian Water Quality Guidelines 1987) was exceeded in the manured treatments at all sites. Site L and M Control also had groundwater concentrations exceeding the 10 mg/ℓ NO3-N limit.

SUMMARY

NO3-N concentrations in soil and shallow groundwater were higher under irrigated, manured conditions at four out of five sites. Statistically significant increases in total and depth-weighted soil NO3-N content under manured conditions were found at Sites B and C. Further investigations of agronomic practices and direction of groundwater movement at each site will be forthcoming.

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WATER QUALITY IN IRRIGATION DISTRIBUTION SYSTEMS

Tracey Bolseng[1]

INTRODUCTION

The total amount of water diverted to irrigation districts in Alberta has increased 62%, from 1,661,000 dam^3 [2] in 1972 to 2,639,000 dam^3 in 1984. Concurrently, there has been a decrease in irrigation return flow from 33% (548,000 dam^3) in 1972 to 21% (545,000 dam^3) in 1984 (Barnetson 1985). Reductions in the percentage of return flow are attributed to: an increase in irrigated acres; rehabilitation of irrigation distribution systems (eg. lined vs unlined canals) and a significant changeover from gravity-feed to sprinkler irrigation, thus making more efficient use of irrigation water (Environment Canada 1985).

Irrigation return flow volumes are of sufficient magnitude that any degradation in water quality in the irrigation distribution system can have a major impact on receiving steams. Oosterveld et al. (1978) found the quality of irrigation return flow is similar to the original water supply, with only a slight increase in salinity. Hamilton et al. (1982) demonstrated that some irrigation return flow has high salt concentrations, which suggests salt loading from soil leaching or groundwater sources. This same study, however, concluded that irrigation return flow has not significantly impacted on water quality in the South Saskatchewan River Basin.

In addition to salts, other potential contaminants of concern include nitrates, trace elements, and pesticides. Potential sources for these contaminants include subsurface drainage effluent, non-point source surface runoff and groundwater.

In order to assess if irrigation water is undergoing degradation, the Land Evaluation and Reclamation Branch has begun to compile a database on water quality in irrigation distribution systems.

METHODS

Since June 1989, irrigation water samples have been collected on a biweekly basis during the irrigation season at 18 hydrometric stations located along canals/laterals in the LNID, TID and UID (Figures 1, 2, and 3). Most stations are paired along the upper and lower reaches of laterals. Flow monitoring and sample collection was conducted at all stations by the Irrigation Branch. Water samples were analyzed for pH, EC, SAR, cations, anions and nutrients (NO3-N, P) using standard analytical techniques. A limited number of samples were analyzed for trace elements (Se in 1989 and Se, Pb, As, Cd, Mn, Fe and Mo in 1990) employing the atomic absorption method.

RESULTS AND DISCUSSION

LNID

The mean EC at all LNID stations for both sampling years remains

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[2]dam = 1000 meters cubed

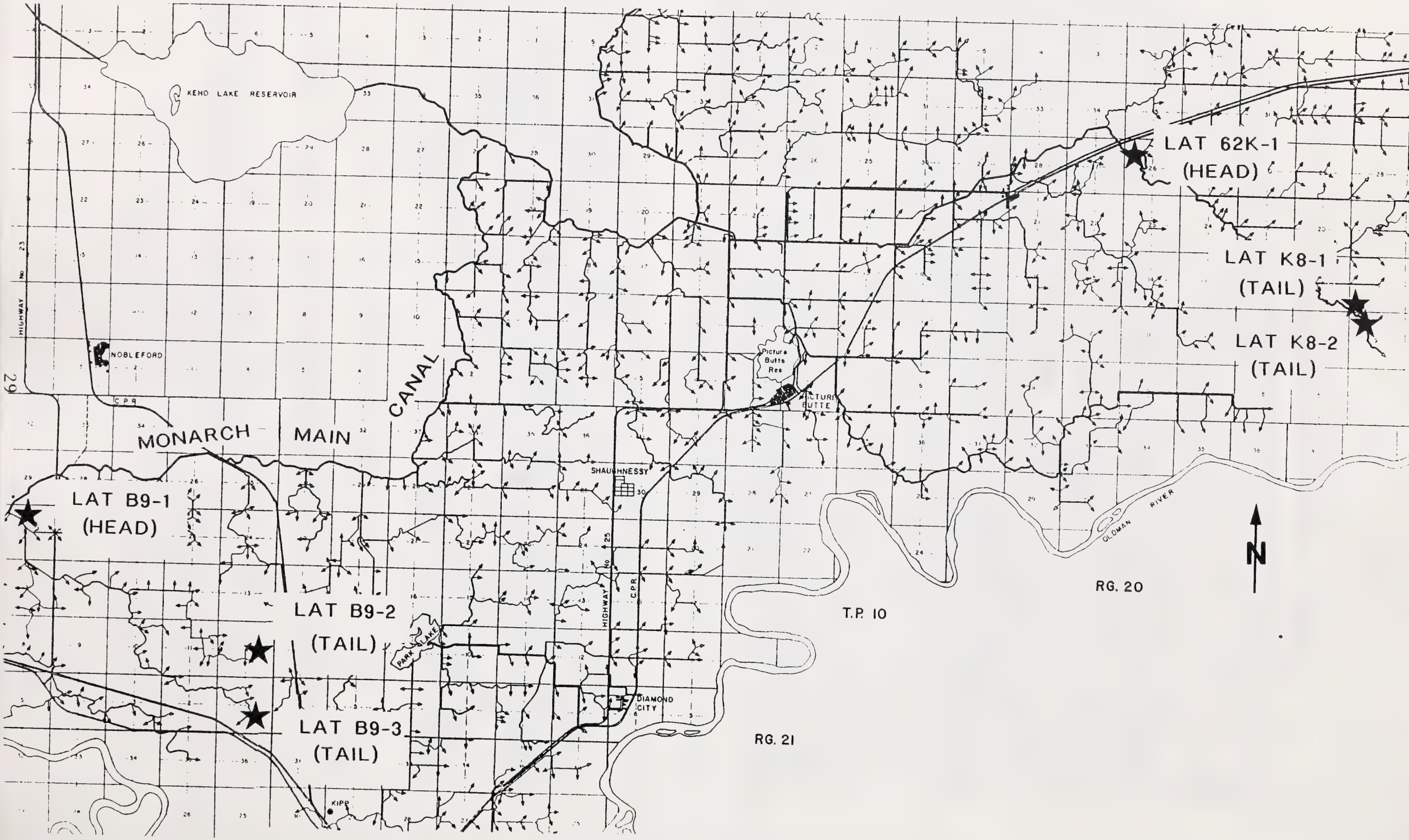

FIGURE 1. Water quality sampling sites in LNID during 1989/90.

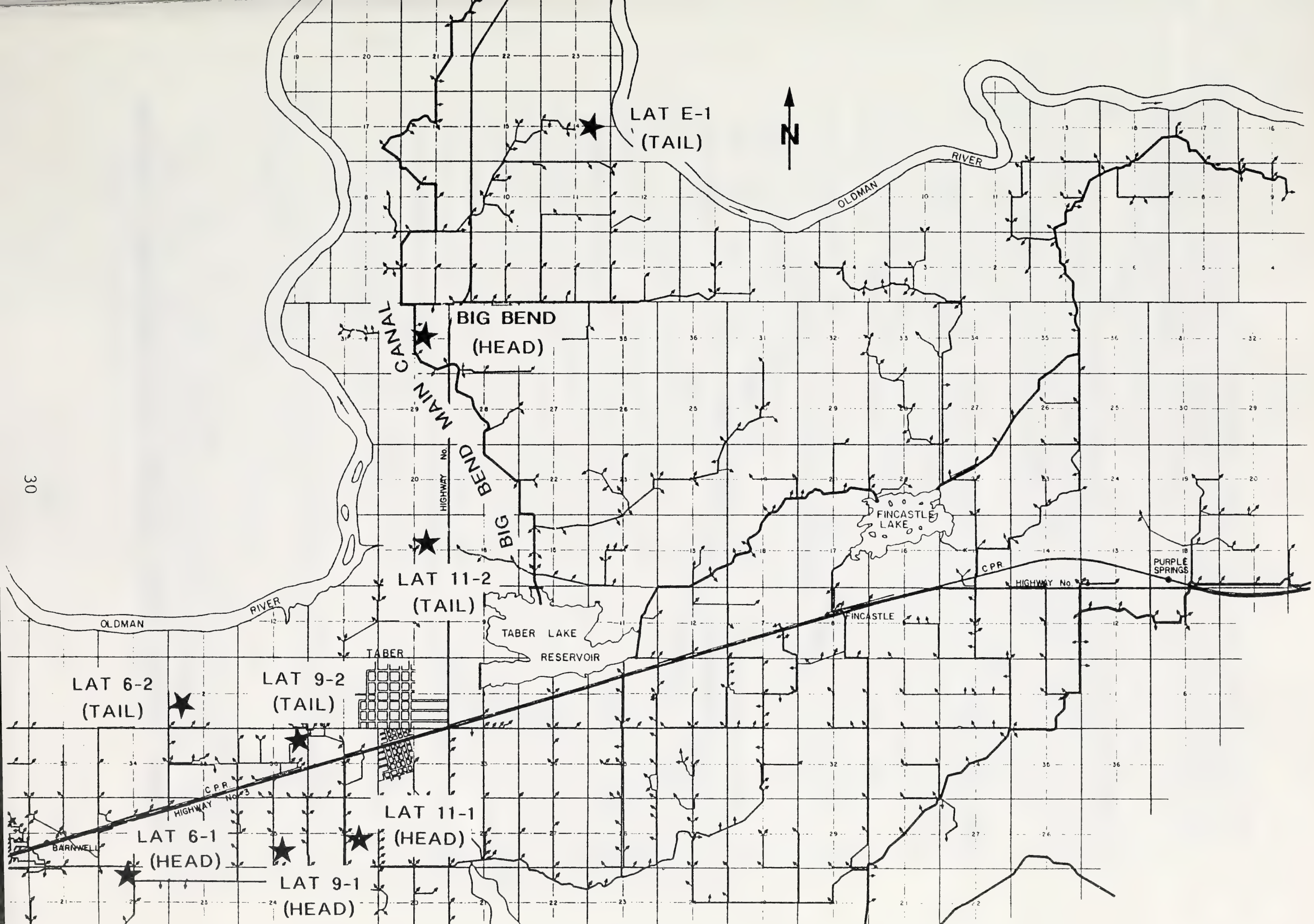

FIGURE 2. Water quality sampling sites in TID during 1989/90.

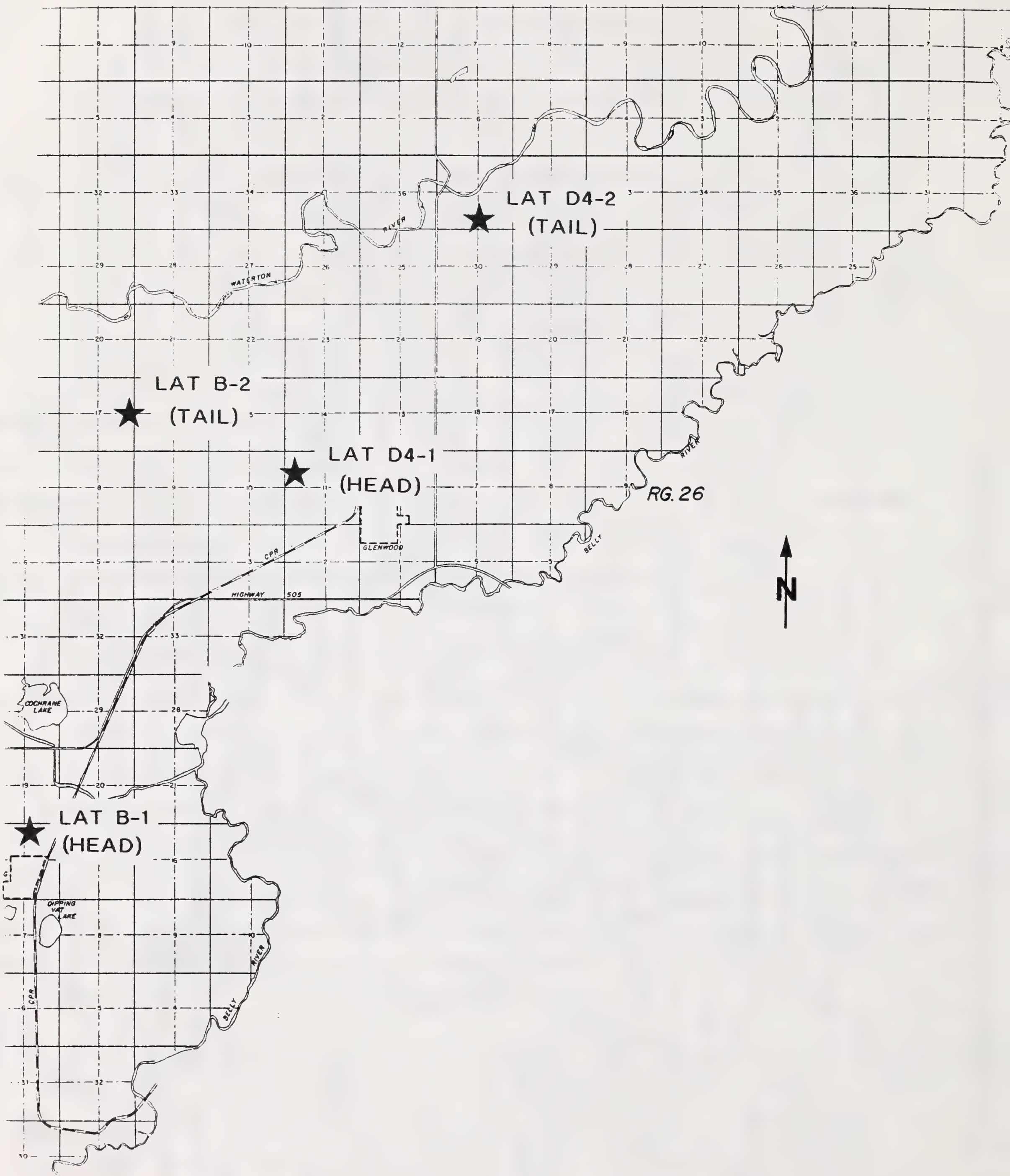

FIGURE 3. Water quality sampling sites in UID during 1989/90.

constant at approximately 0.30 dS/m indicating no salt loading along the distribution system. The standard deviation (0.01 to 0.05) reflects the consistency of the data. The mean SAR of the individual head and tail systems remain unchanged, but vary between the systems and sampling years (Table 1a).

TID

The mean EC for all TID stations in 1989 and 1990 is constant at 0.25 to 0.26 except for the Big Bend and Lateral E system where the EC is higher at 0.33 ± 0.1 in 1989 and 0.39 ± 0.09 in 1990. The mean SAR of the TID head and tail stations remain unchanged within the individual systems, but vary between systems and sampling years (Table 1b).

UID

Mean EC levels for the UID laterals are slightly higher at the tail stations as compared to the head stations in both 1989 and 1990 (Table 1c). Lateral B-2 has the highest mean EC and largest standard deviation of all stations in both sampling years. The increased salt levels in Lateral B-2 is attributed to single samples taken at low flow early in each sampling year (June 1989 and July 1990).

Trace Elements

Most of the trace elements results (Table 2) were below the detection limit and well within the Canadian recommended maximum limit for human consumption of water.

Table 2. Trace Element Results†

Substance	Result (mg/ℓ)	Recommended Maximum Limit‡
Arsenic (As)	< 0.0003° - 0.0027	0.05
Cadmium (Cd)	< 0.03°	0.0005
Iron (Fe)	< 0.10°	0.3
Lead (Pb)	< 0.03°	0.05
Maganese (Mn)	< 0.03°	0.05
Molybdenum (Mo)	< 0.1° - 0.2	0.5+
Selenium (Se)	< 0.0005° (1989) < 0.001°	0.01

† All results are for 1990 unless indicated.
‡ Canadian Water Quality Guidelines (1987).
\+ USSR Water Quality Limit (1970).
° Detection limit.

NO3-N levels in all water samples were low, ranging from < 0.1 to 0.2 mg/ℓ, and well within the 10 mg/ℓ limit recommended for human consumption of water.

CONCLUSIONS

From the data collected during 1989-90 there appears to be no degradation in water quality in irrigation distribution systems. The water quality meets, or is better than, the recommended limits for surface water set out by the Canadian Water Quality Guidelines (1987). This data will be used as baseline information for future investigations into irrigation water quality.

Table 1a. 1989-90 LNID STATIONS

STATION	1989		1990	
	EC	SAR	EC	SAR
H'LAT 62K-1	0.30" ± 0.01	0.33 ± 0.10	0.30 ± 0.02	0.43 ± 0.09
T LAT K8-1	0.30 ± 0.01	0.33 ± 0.10	0.31 ± 0.02	0.44 ± 0.12
T LAT K8-2	0.30 ± 0.01	0.34 ± 0.07	0.30 ± 0.02	0.43 ± 0.11
H LAT B9-1	0.30 ± 0.05	0.25 ± 0.12	0.29 ± 0.04	0.23 ± 0.05
T LAT B9-2	0.29 ± 0.02	0.21 ± 0.07	0.28 ± 0.04	0.23 ± 0.05
T LAT B9-3	0.28 ± 0.03	0.21 ± 0.06	0.29 ± 0.04	0.29 ± 0.16

Table 1b. 1989-90 TID STATIONS

STATION	1989		1990	
	EC	SAR	EC	SAR
H'LAT 11-1	0.25" ± 0.02	0.26 ± 0.09	0.26 ± 0.03	0.37 ± 0.07
T LAT 11-2	0.25 ± 0.02	0.29 ± 0.08	0.27 ± 0.03	0.37 ± 0.07
H LAT 6-1	0.25 ± 0.02	0.30 ± 0.08	0.26 ± 0.03	0.38 ± 0.07
T LAT 6-2	0.25 ± 0.02	0.28 ± 0.07	0.27 ± 0.03	0.36 ± 0.05
H LAT 9-1	0.25 ± 0.01	0.28 ± 0.10	0.26 ± 0.03	0.34 ± 0.05
T LAT 9-2	0.25 ± 0.02	0.28 ± 0.07	0.27 ± 0.03	0.34 ± 0.05
H BIGBEND-2	0.33 ± 0.10	0.90 ± 0.35	0.38 ± 0.09	1.11 ± 0.22
T LAT E-1	0.33 ± 0.10	0.89 ± 0.34	0.40 ± 0.09	1.13 ± 0.19

Table 1c. 1989-90 UID STATIONS

STATION	1989		1990	
	EC	SAR	EC	SAR
H'LAT B-1	0.20" ± 0.03	0.14 ± 0.05	0.20 ± 0.04	0.17 ± 0.08
T LAT B-2	0.34 ± 0.28	0.30 ± 0.22	0.36 ± 0.19	0.35 ± 0.20
H LAT D4-1	0.19 ± 0.02	0.19 ± 0.04	0.27 ± 0.10	0.33 ± 0.17
T LAT D4-2	0.28 ± 0.09	0.36 ± 0.14	0.27 ± 0.07	0.38 ± 0.12

" Mean sampling dates at each station ± standard deviation.
' Head or Tail station. See Figures 1, 2 and 3 for locations.

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OXYGEN-18 AND DEUTERIUM IN PRECIPITATION AND TILL IN SOUTHERN ALBERTA

Joan Rodvang[1]

INTRODUCTION

Water is composed mainly of oxygen-16 and hydrogen-1, but it also contains significant amounts of the heavier isotopes oxygen-18 and hydrogen-2, or deuterium. In precipitation and groundwater which have not been affected by evaporation, the ratio of oxygen-18 to deuterium remains constant. Waters which are subjected to evaporation become progressively enriched in oxygen-18 relative to deuterium.

Based on oxygen-18 to deuterium ratios, Hendry (1986) concluded groundwater in shallow weathered till in southern Alberta has been altered by evaporation and, therefore, significant vertical movement of water occurs in shallow tills. Such movement is critical for the maintenance of adequate drainage under irrigation. As a standard for non-evaporated water, Hendry (1986) used the average global relationship between oxygen-18 and deuterium in precipitation, called the global meteoric water line. However, in arid climates precipitation tends to have a lower slope than the global meteoric water line due to evaporation during precipitation.

The main goal of this investigation was to determine the slope of the local meteoric water line for Lethbridge. In addition, the meteorological controls on the isotopic signature of precipitation in the area were investigated to provide further information on the origin and degree of evaporation of groundwater in weathered and unweathered tills in southern Alberta.

METHODS OF INVESTIGATION

Precipitation samples were collected in Lethbridge between February 1987 and July 1989. Groundwater samples were collected from piezometers completed in till from four regions located within 100 km of Lethbridge (Figure 1). Samples from Site 1 were collected in 1989, and by Robertson (1988). Samples from Site 2 were collected by Stein (1987), while samples from Sites 3 and 4 were previously reported by Hendry (1988). The study incorporated 5 snow samples collected from Site 1. Sites 1 and 2 are under dryland practices, while Sites 3 and 4 are irrigated.

Oxygen-18 and deuterium were measured on precipitation and groundwater samples using mass spectrometry. All precipitation samples, and the majority of groundwater samples, were analyzed by the Institute for Groundwater Research at the University of Waterloo. Groundwater

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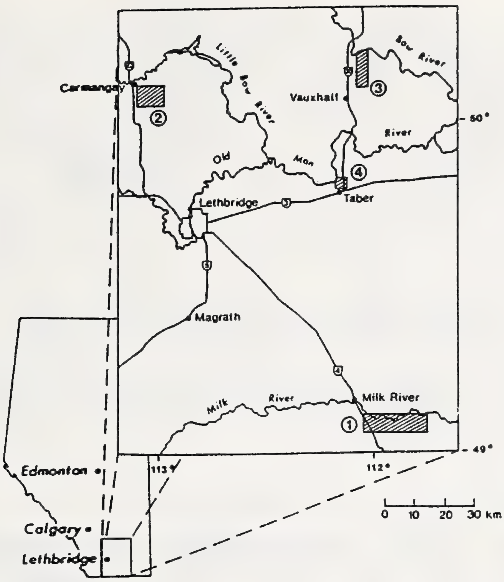

Figure 1. Location of Study Sites.

samples collected by Stein (1987) were analyzed at the University of Calgary.

Meteorological data for Lethbridge was obtained from daily records maintained by Agriculture Canada in Lethbridge.

RESULTS

Oxygen-18 (18O) and deuterium (D) levels in precipitation vary with temperature and, to a lesser degree, with the origin and history of the air mass which produced it. Precipitation is more depleted in heavy isotopes on cooler days (Figure 2). O-18 content was generally lowest in winter months, with a difference of up to 32.5 parts per thousand (called per mil, and denoted %) between summer and winter (Figure 2). 18O increased by about 0.6 %. per degree C increase in air temperature, with a correlation coefficient of 0.77 (data not shown).

On a global basis there is a linear relationship between 18O and D in precipitation. This relationship is called the global meteoric water line (Figure 3). The local meteoric water line for Lethbridge exhibited a lower slope than the global meteoric water line (Figure 3).

As explained by Dansgaard (1964), it is not uncommon for the isotopic content of precipitation at local stations to exhibit lower slopes than the globally averaged meteoric water line. These lower slopes are usually due to evaporation and mixing with air during precipitation events. Transpiration and evaporation from open water surfaces do not cause a net change in the 18O to D ratio.

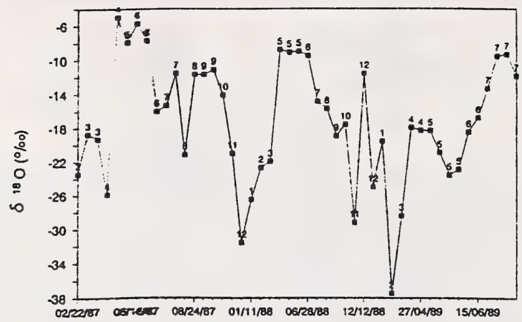

Figure 2. Variation in ^{18}O with seasonal precipitation at Lethbridge, Alberta. Numbers give month of precipitation.

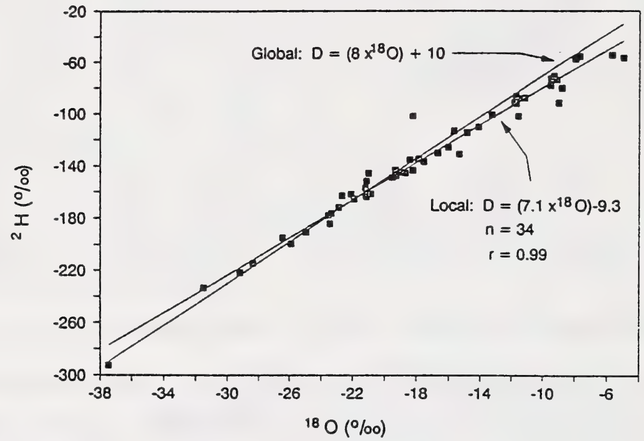

Figure 3. Meteoric Water Line for Lethbridge, Alberta, in Relation to the Global Meteoric Water Line.

The deuterium excess parameter, d, where $d = \bar{D} - 8 \times \overline{O18}$, is a measure of the evaporation rate. d decreases in precipitation as the evaporation rate increases. The average deuterium excess parameter for continental North America is +10 (Dansgaard, 1964). The average d for Lethbridge precipitation was 6.4, indicating evaporation during precipitation. The average d for rain was only 3.2, while that for snow was 11.9, which suggests that, on average, evaporation from falling snow is minimal.

Oxygen-18 and deuterium in groundwater are affected only by evaporation, and therefore, the isotopic composition of groundwater is generally very similar to the average isotopic composition of precipitation in the recharge area. The weighted mean isotopic compositions of rain, snow, weathered till and unweathered till, along with their regression lines, are shown in Figure 4. The regression line for unweathered till had a slope of approximately 8, indicating it had

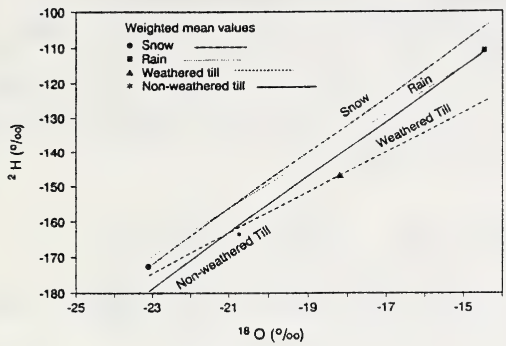

Figure 4a. Weathered Till vs. Non-weathered Till and Precipitation

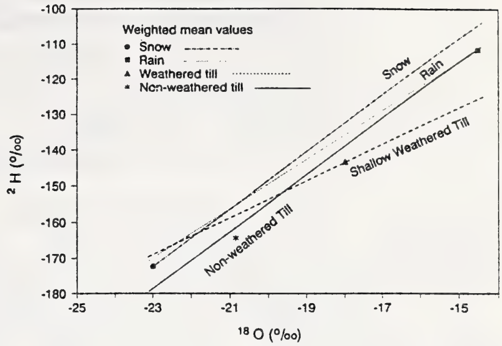

Figure 4b. Shallow Weathered Till vs. Non-weathered Till and Precipitation.

not been affected by evaporation. However, the d parameter for non-weathered till (5.1) was less than that for snow (11.9). The lower d of water from the non-weathered till suggests that it condensed from a vapor which evaporated more slowly than that of present snow. This is consistent with the hypothesis that groundwater in the non-weathered till is of glacial age (Hendry, 1986), and formed from vapor which evaporated under glacial conditions.

In contrast to water from the non-weathered till, water from the weathered till to a depth of 35 m fell on a regression line with a slope of 5.7 (Figure 4a), indicating it had been modified by evaporation after precipitation. This evaporation line intersects the non-weathered till at its mean composition, and intersects the snow line below its mean composition. This suggests water from the weathered till originated from water which had an average composition more depleted than modern snow, and similar to water from which non-weathered till originated (i.e. glacial water). The same regression lines are shown again in Figure 4b, this time in comparison to weathered till from groundwater installations shallower than 9 m. Although these shallow samples exhibit a slope which is similar to groundwater from deeper in the weathered till, they intersect the snow line at a point slightly more enriched than modern snow, suggesting that water in the shallow weathered till originated mainly from snow-melt, with minor amounts of rain.

The shape of the profiles of 18O and D with depth in groundwater of southern Alberta till, also exhibit evidence of evaporation following precipitation. Isotopic enrichment is at a maximum near the water table, and decreases with depth to values similar to present-day snow (data not shown).

CONCLUSIONS

The isotopic variation in modern-day precipitation in southern Alberta is influenced by temperature and, to a lesser degree, by potential evapotranspiration. Rain exhibits the effects of evaporation during precipitation, while snow does not.

Groundwater in the non-weathered till in southern Alberta does not exhibit evaporative effects. Its deuterium excess indicates that it originated at temperatures colder than present-day values, which suggests that it recharged the till during glacial times. In contrast, the isotopic signature of groundwater in weathered till suggests that it originated from snow with a minor component of rain, and that it has been affected by evaporation during recharge.

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HYDROGEOLOGIC INVESTIGATION OF POTENTIAL SEEPAGE FROM KEENEX COULEE AS A RESULT OF PROPOSED WETLANDS DEVELOPMENT

Joan Rodvang[1]

INTRODUCTION

Keenex Coulee is a glacial drainage channel located west of Nobleford, Alberta (Figure 1). In 1988 Ducks Unlimited requested permission to develop a wetland habitat by raising the water levels in the marshes which presently occupy the channel. In addition, four small ponds would be formed in borrow pits (Basin 6 in Figure 1).

The current investigation was undertaken to investigate the potential for the proposed development to cause salinization and waterlogging in the surrounding area.

METHODS OF INVESTIGATION

Testholes were drilled in March 1989 at 43 locations along nine cross-sections (Figure 1). Testholes were deeper than the minimum elevation in the bottom of the proposed wetland channels. Soil samples were collected from each testhole for the determination of saturation paste extract chemistry (Rhoades 1982). A water-table well and one to two piezometers were installed at each testhole location. Piezometers were flushed with water and bailed dry to remove contamination. Water levels in water tables and piezometers were monitored monthly between March 1989 and January 1990. Hydraulic conductivities were measured using the single-well-response-test method on most piezometers. In addition, seven shallow-well pump-in tests were conducted to determine the hydraulic conductivity of the shallow overburden. Samples were collected from most piezometers and water-table wells to determine major ion groundwater chemistry.

A three-dimensional finite-difference groundwater-flow model (MODFLOW, developed by McDonald and Harbaugh, 1988) was used to predict the effect of the proposed development on water-table levels and hydraulic gradients in the surrounding area.

RESULTS

The upper Cretaceous St. Mary River Formation subcrops beneath the study area. This formation consists of finely interbedded and discontinuous layers of sandstone, shale and mudstone. The bedrock surface slopes towards Keenex Coulee from the east and west. The bedrock also slopes gently to the north beginning at the south end of

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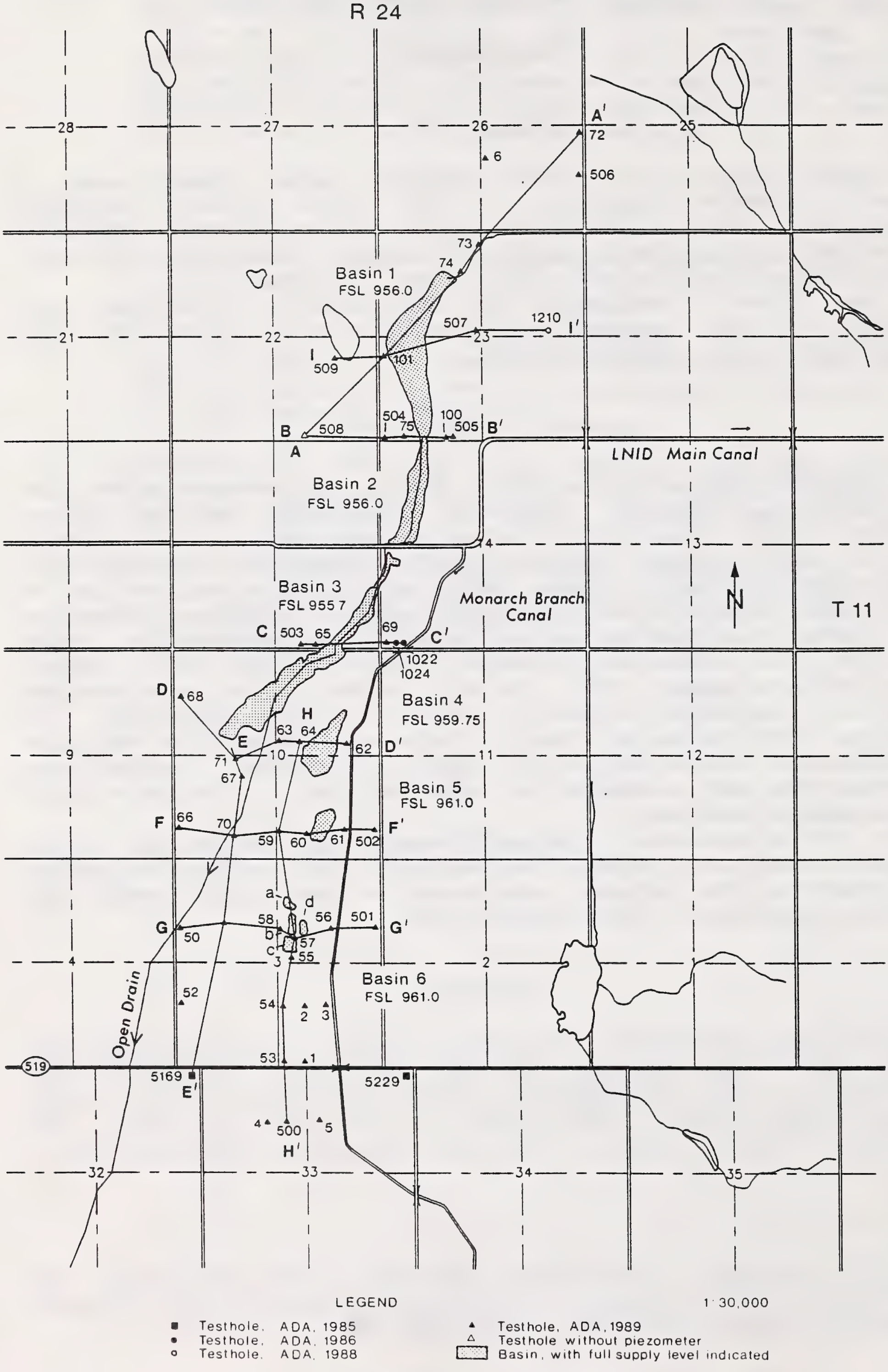

Figure 1. Location of testholes and cross-sections.

Basin 1. Bedrock is deeply eroded, to a depth of at least 10 m, in the bottom of the glacial channel.

The study area is blanketed by glaciolacustrine deposits, which are underlain by till in some places, and in other places directly by bedrock. The overburden varies from 1 to 3 m thick in the area, increasing to over 10 m in the channel. Overburden textures ranged from clay loam to sandy clay loam. Lacustrine deposits were often interbedded with sand and silt layers.

The bottom of the proposed basins occur in till, lacustrine material, or bedrock.

Hydraulic conductivity values measured in the St. Mary River Formation ranged from 10^{-10} to 10^{-5} m/s, with a mean of 10^{-7} m/s. Overburden hydraulic conductivity values measured using the shallow-well pump-in method (mean of 10^{-6}) were one to two orders of magnitude higher than those obtained using the single-well-response-test method (mean of 10^{-7}). It is thought that conductivities obtained using the former method are higher because the tested material is shallower, and therefore less consolidated and more weathered, than material tested using piezometers.

Surface topography and groundwater gradients are a muted copy of the bedrock surface. Natural water-table gradients are directed towards Keenex Coulee from the east and west, but the gradient is more gradual to the west than to the east. Water-table gradients to the north and south of the basin are quite flat (Figure 2). The water table occurs mainly in the bedrock but, due to topography, it occurs at shallower depths in the overburden in the vicinity of the glacial channel. Groundwater discharges in the coulee.

Electrical conductivity (EC) values measured on soil samples ranged from less than 1 to 27.5 dS/m in the upper 1 m of soil. Testholes which exhibited high salinity corresponded to sites with saline groundwater, and tended to occur in discharge areas associated with the coulee.

An initial estimate of the effect of basin development was obtained by plotting cross-sections which compared the natural water table to the full supply level (FSL) proposed for each basin. Water-table gradients from all basins were steep enough to prevent seepage from travelling any appreciable distance to the east. Water-table gradients would also continue to be directed towards Basins 1, 2 and 3 from the west. Potential seepage to the west from Basins 4, 5 and 6 could raise the water table between these basins and the open drain which runs 250, 700 and 900 m west of Basins 4, 5 and 6, respectively (Figure 1). The proposed FSL levels will also cause slight gradients to the north from Basin 1 and to the south from Basin 6.

Mathematical flow modelling was used to characterize the potential for seepage to the north from Basin 1, and to the west and south from Basin 6. The areas around Basins 1 and 6 were discretized into rows and columns, and 3 layers were used to represent geologic layering. The drain was treated as a constant-head boundary, and other boundaries were treated as constant-flow boundaries. The model was calibrated by adjusting the horizontal and vertical hydraulic conductivity values until the simulated hydraulic heads were in close agreement with the measured heads. Once the model was calibrated, model cells containing basins were changed to constant-head cells equal to the proposed FSL.

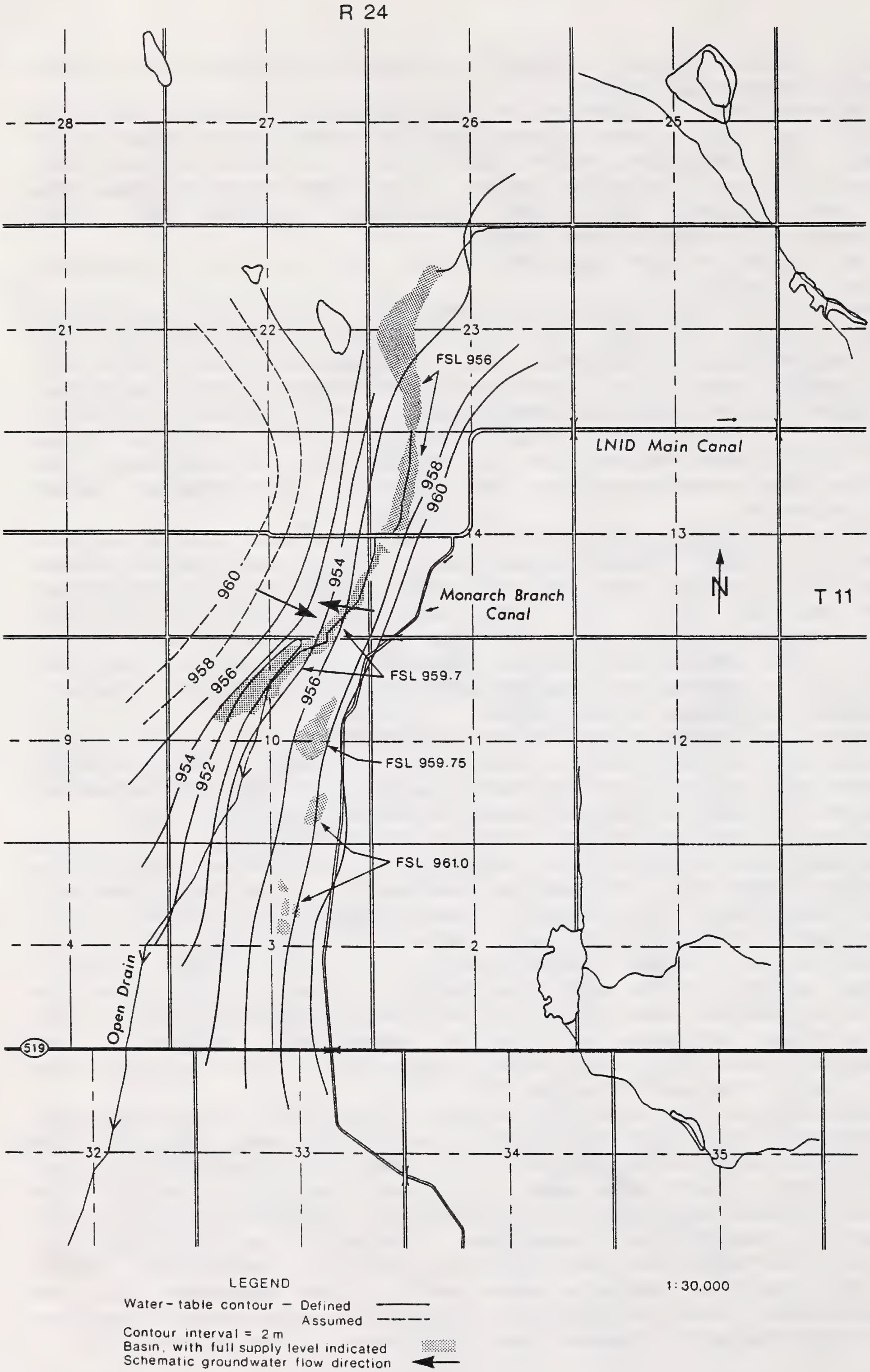

Figure 2. Water-table elevation, June 1989.

The results of model simulations indicated that the water table would rise by at least 0.5 m over a 100 ha area around Basin 6, and would affect areas which are currently non-salinized. The model results indicated that, as a result of the development of Basin 1, the water table would rise by less than 30 cm to the north of Section 23-11-24-W4, and would affect an area which currently exhibits salinity associated with the glacial channel.

CONCLUSIONS

Surface water and shallow groundwater drain towards the glacial bedrock channel called Keenex Coulee from the east and west. A shallow water table and groundwater discharge has caused most of the channel to be salinized. Raising the water levels in the channel and associated depressions to the levels proposed by Ducks Unlimited will not increase the potential for seepage to the east, due to the steepness of the water-table rise in that direction. The water-table gradient to the west is more gentle, and there is a potential for the water table to rise in that direction as a result of basin development. Natural water-table gradients to the north and south of the proposed development are very gentle, and there is a potential for seepage to the north and south. Groundwater flow modelling predicts that the development of Basins 1 and 6 will cause the water table to rise slightly to the north of Basin 1 and to the west and south of Basin 6.

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GROUNDWATER QUALITY IN THE BOW RIVER AND TABER IRRIGATION DISTRICTS

Joan Rodvang[1]

INTRODUCTION

Agricultural practices such as fertilization, and the application of pesticides and herbicides, can potentially decrease the quality of groundwater, particularly where groundwater recharge may be increased by irrigation. The major ion chemistry of groundwater has been determined in many places in southern Alberta. However, the trace element and organic content of groundwater has been determined at only a few locations within the irrigation districts.

The purpose of this investigation was to update a database of shallow groundwater chemistry in two irrigated areas of southern Alberta. This database will allow for the detection of changes in groundwater chemistry which may have occurred over the last ten years, and will provide an updated baseline to which future samples collected from the area can be compared.

THE STUDY AREA

Groundwater return flow studies were conducted in the Bow River and Taber Irrigation Districts (BRID and TID) by Alberta Agriculture staff in the early 1980's (Hendry 1981; Hendry et al. 1982). Those studies characterized the groundwater flow regimes in the two areas shown in Figure 1. Major ion concentrations were determined from 159 piezometers or water-table wells at 56 sites. Most piezometers were within 30 m of ground surface, with a few being up to 50 m deep.

The BRID and TID study areas exhibit geology which is characteristic of southern Alberta. Both sites are underlain by glacial till overlying bedrock consisting of flat-lying interbedded sandstone, siltstone and shale. Sand layers and lenses are common at the surface and within the till. The upper 10 to 25 m of till was oxidized during a time of lower water table which occurred between 11,000 and 3,000 years ago.

METHODS OF INVESTIGATION

During the current investigation, 77 piezometers and water-table wells from the Bow River and Taber Groundwater Return Flow studies were re-sampled for major ions, and trace element concentrations were determined for the first time.

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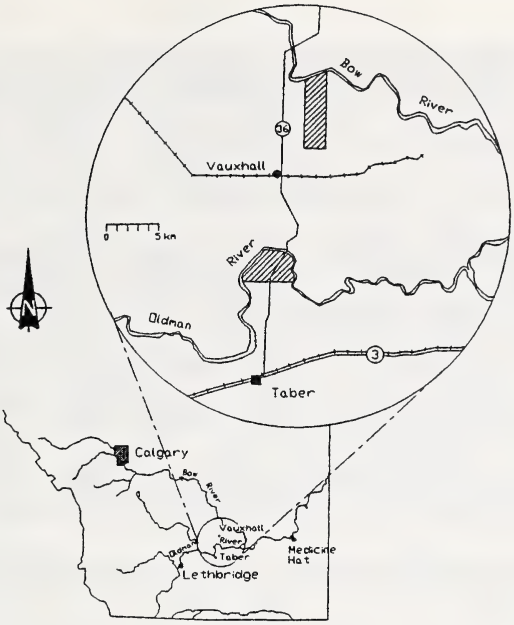

Figure 1. Location of Study Sites.

All piezometers and water-table wells were bailed to dryness twice before sampling. Piezometers which were contaminated were flushed with water before being bailed twice. Samples were collected using a bailer, which was rinsed with distilled water before collecting each sample. Samples were collected in two, 250 mL polyethylene bottles, which were thoroughly washed, and rinsed with 10% HCL and deionized water prior to going in the field. Sample bottles were also rinsed with formation water before being filled. pH and temperature were measured in the field. Samples were transported to the lab in ice-filled coolers, and filtered in the lab on the day of collection, through 0.45 μm filter paper. One sample was acidifed to pH < 2 for the determination of cations.

Major ion and trace element concentrations were compared to the Canadian Water Quality Guidelines (1987).

RESULTS

A comparison of groundwater chemistry from samples collected in 1990 with those collected in 1979-80, indicated that most samples were very similar. A small proportion of 1990 samples exhibited significantly lower ion concentrations. This is thought to be the result of flushing of piezometers with water followed by inadequate bailing, and these results were therefore omitted from discussion.

No continuous or significant trends were observed between the 1979-80 data and the 1990 data, and paired univariant t-tests indicated that the two populations were not statistically different. The following discussion of groundwater chemistry therefore treats the two sample sets as a unit.

Groundwater in the till, bedrock and intertill sands all exhibited very high major ion concentrations, dominated by sodium, sulfate, bicarbonate, calcium and magnesium. Sodium and sulfate exceeded Canadian drinking water guidelines (270 and 500 mg/L, respectively) in 85% of samples. Calcium and magnesium also exceeded drinking water guidelines (200 and 150 mg/L, respectively) in most samples. Chloride concentrations were quite high in most samples, but did not exceed the drinking water guideline of 600 mg/L. Potassium occurred at low concentrations. Major ion concentrations varied over a wide range, particularly in the weathered till.

The range and median values of major ion concentrations are listed in Table 1. Groundwater in the weathered till exhibited the highest major ion concentrations, and buried sand deposits tended to have compositions similar to the surrounding till. Samples with relatively low major ion concentrations were collected mainly from the shallow weathered till or shallow sand deposits, where it is expected that the system has been partially flushed with infiltrating precipitation or

Table 1. Medians and ranges of major ion concentrations measured in groundwater in the BRID and TID.

(mg/ℓ)

	SURFACE SAND		WEATHERED TILL		BURIED SAND		NONWEATHERED TILL		BEDROCK	
Ion	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median
Sulfate	48-9167	1230	48-16162	4277	275-7301	3814	31-5331	2172	50-6916	1725
Sodium	41-2690	278	32- 6092	1575	90-3515	1623	16-1651	745	444-3313	1127
Calcium	30- 519	2323	38- 3527	411	36- 471	405	20- 609	317	6- 505	58
Magnesium	19- 948	158	11- 1964	267	9- 496	198	6- 341	125	1- 378	23
Chloride	70- 680	35	20- 921	56	3- 690	198	20- 248	32	18- 492	219

irrigation water. Relatively low salt concentrations also occurred in the unweathered till in some places.

The majority of samples exhibited very low nitrate levels. However, nitrate levels which exceeded the Canadian drinking water guideline of 10 mg/L nitrate nitrogen (NO3-N) occurred in all deposits, at up to 30 to 40 times the recommended limit. Of those samples collected from buried sand deposits, 57% contained nitrate in excess of drinking water limits, followed by weathered till at 34%, surface sand at 26%, and finally, by non-weathered till and bedrock at 15 to 18%.

Low levels of arsenic were detected in most samples. While arsenic was detected in all groundwaters from till and bedrock, to the maximum sampling depth of 51 m, most of the highest arsenic levels occurred in shallow till or surface sand deposits. The drinking water limit of 0.05 mg/L was not exceeded in any samples. Low levels of selenium were detected in 16 samples collected from buried sand layers and sandstone bedrock. The drinking water guideline of 0.01 mg/L was exceeded in three samples.

Cadmium was not detected in any samples, while very low levels of lead were detected in ten samples, and low levels of molybdenum occurred at most depths at one site.

DISCUSSION

High concentrations of sulfate, sodium, calcium and magnesium are the result of natural weathering of compounds native to the till, including the oxidation of reduced sulfur, dissolution of carbonate minerals, and exchange of calcium and magnesium for sodium on clay surfaces (Hendry 1981; Hendry et al. 1982). Similar chemical weathering reactions occur throughout shallow till deposits in Canada (Van Stempvoort 1990; Rodvang 1987). Major ions enter the groundwater mainly in the weathered till zone, and are transported to the buried sand and unweathered till. Salt content is often lower in the unweathered till due to attenuation mechanisms (Hendry 1981). The wide range in salt concentrations are the result of variations in weathering rates and flow rates and patterns.

Some chloride may be entering the groundwater through anthropogenic sources. Hendry et al. (1982) note that 5:1 extract analyses of soil indicate that chloride levels in soil are not high enough to be a source of dissolution for the amount of chloride which occurs at some sites.

Although arsenic and selenium are components of some pesticides and herbicides, they are also commonly associated with sulfide minerals (Hem 1985). Therefore, minor amounts of minerals such as arsenopyrite (FeAsS) or impure pyrite may be incorporated in the till and bedrock. Since arsenic and selenium tend to occur as isolated pockets at all depths, it is probable that they come from a natural source. Selenium and arsenic concentrations in water are limited by their low solubility (Hem 1985). Lead is widely dispersed in sedimentary rocks, but its solubility in water is low.

The application of fertilizer and manure to soil can potentially cause nitrate contamination of groundwater. Hendry et al. (1984) concluded that high nitrate levels at the TID site under investigation were not the result of contamination, but rather were the result of nitrification of ammonium which was incorporated in the till during deposition. Measured nitrate levels remained quite stable between 1980 and 1990; samples which previously exhibited low levels continued to exhibit low levels, and samples which exhibited high levels showed no significant trends. This supports Hendry et al.'s (1982) hypothesis that the nitrate is not a contaminant in the area. The tendency for most high nitrate values to occur in buried sand layers is consistent with the hypothesis (Hendry et al. 1984) that isolated enclaves of high nitrate occur where conditions are less favorable for denitrification.

CONCLUSIONS

No significant trends of increasing or decreasing major ion concentrations were observed in shallow or deep groundwater between 1980 and 1990 at two irrigated areas in the BRID and TID. High concentrations of sodium, sulfate, calcium, magnesium and bicarbonate in weathered till, intertill sand layers and bedrock are the result of

natural weathering and dissolution processes. Some high salt concentrations also occur in the unweathered till where ions have been transported down from the weathered zone. High nitrate concentrations in isolated pockets in surficial and bedrock deposits remained relatively stable over the last ten years, supporting the hypothesis that nitrate originates as a natural weathering product rather than as a contaminant.

Low levels of arsenic, selenium and lead were detected in many samples, and drinking water guidelines for selenium were exceeded in a small proportion of samples. These metals probably result from weathering of minerals incorporated in the till during deposition.

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RIVER ROAD IRRIGATION IMPACT STUDY

Joan Rodvang[1]

INTRODUCTION

The purpose of this study is to determine the amount of recharge occurring under irrigation at one irrigated site in the Milk River area (Figure 1). The study was originated in the fall of 1988 with the objective of monitoring potential leaching of major ions to greater depths as the result of irrigation. In 1989 the investigation was expanded to include monitoring soil moisture content throughout the growing season.

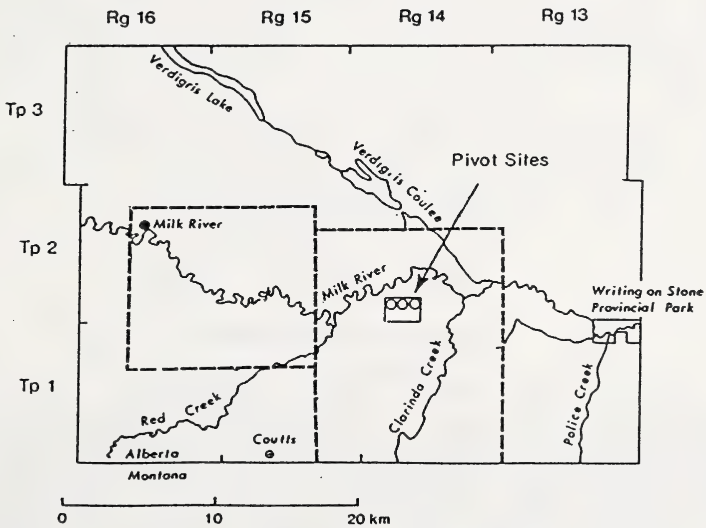

Figure 1. The Study Area.

METHOD OF INVESTIGATION

Since 1988, major ion concentrations have been determined using saturation paste extract tests (Rhoades, 1982), on soil samples collected in the spring and fall of each year. Originally samples were collected at 30 cm intervals to a depth of 1.5 m. In the fall of 1989 sampling depth was increased to the depth of refusal, which occurred at bedrock or gravel overlying bedrock. In the spring of 1989 neutron access tubes were installed at all sampling sites, and moisture content was measured with a neutron probe on a bi-weekly basis throughout the

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growing seasons of 1989 and 1990. Initially, nine sampling sites were located below three centre pivots, and three control sites were located outside the pivot circles. In the spring of 1990 six additional control sites were added and the location of some sites were moved due to logistical constraints (Figure 2).

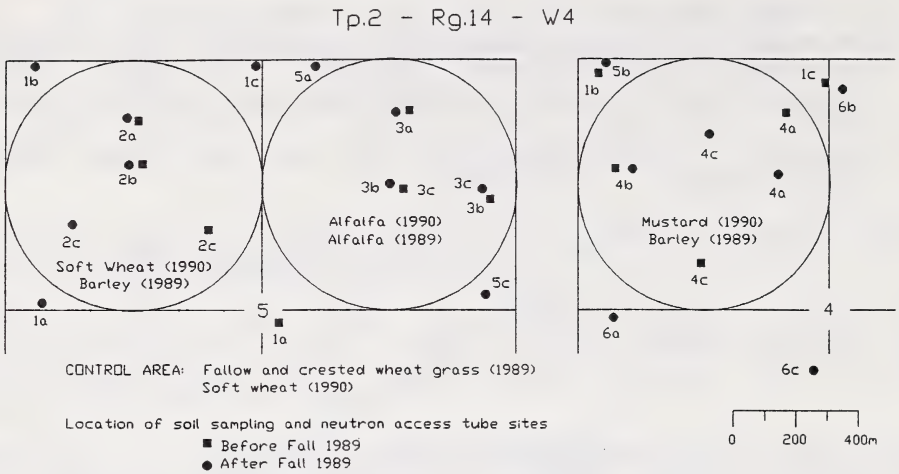

Figure 2. Site Location Plan

During the fall of 1989, core samples were collected from the original twelve sites for the purpose of determining moisture retention characteristic curves, bulk density and grain size. Continuous cores were collected in copper core tubes, which were waxed on the day of collection. Cores have been stored at 4°C since they were collected.

Field textures were determined on each soil sample at the time of collection. Gravimetric moisture contents were determined at 30 cm intervals to refusal during May of 1990.

During the 1990 growing season continuous records of precipitation and irrigation were collected at the site using dataloggers on rain gauges. A weir was installed at the northern end of the site to measure run-off, which was substantial in that area during 1989.

RESULTS

The ground surface and bedrock on the site slope to the northeast at approximately 10 m/km. The overburden ranges from 3 to 5.5 m thick, and consists of till overlying a fluvial deposit. Groundwater flow parallels topography. The water table occurs at approximately 21 m below the pivots. A perched water table occurs at a 2.5 to 4.5 m depth in the northeast corner of the study site.

A total of 27.1 cm of water as irrigation and 11.4 cm of water as precipitation was added to the site between May 31 and October 16, 1990. Substantial run-off occurred following a heavy rain on May 24, 1990.

This run-off washed out the weir, which was subsequently re-installed. However, no further run-off occurred during the season.

Moisture contents at all sites were highest in the spring, and decreased gradually throughout the summer. Based on average moisture content over the growing season, irrigated wheat and mustard showed the highest near-surface moisture contents, followed by irrigated alfalfa, while non-irrigated sites exhibited lower moisture contents above 2 m. The difference in moisture content between irrigated and non-irrigated sites was negligible at a depth of 3.6 m (Figure 3).

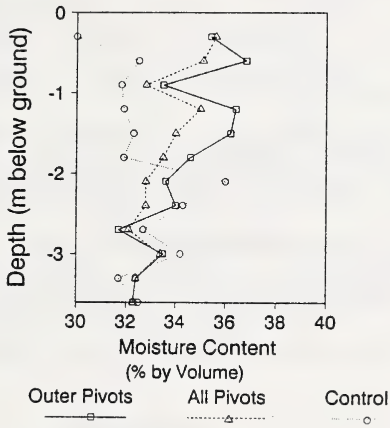

Figure 3: Average Moisture Content Measured during 1990

The largest changes in moisture content over the growing season occurred near the surface, and non-irrigated sites exhibited the largest variation in moisture content to a depth of 2 m (Figure 4). By a depth of 2.4 m, all sites exhibited a standard deviation in moisture content of about 0.5% by volume (Figure 4).

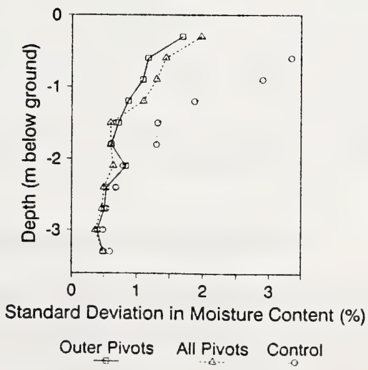

Figure 4: Standard Deviation in Moisture Content Measured during 1990 Season

Gravimetric moisture contents determined in May 1990 ranged from 10 to 35% by volume, with samples at the low end containing a high proportion of sand and gravel. Volumetric moisture contents as determined by neutron probe followed a depth profile similar to those measured gravimetrically, but were generally 5 to 10% higher. This discrepancy occurred because the neutron probe does not measure true moisture content, but a relative moisture content. Since characteristic curves of moisture retention have not yet been determined, field capacity was estimated based on texture. Gravimetric moisture content exceeded field capacity at one or two depths at ten sites, but otherwise was lower than field capacity.

Monitoring of changes in soil chemistry with time was not found to be an effective way to determine leaching rates in this investigation. Chemical profiles collected at different times bore little resemblance to one another, even when two sets were collected in the same month. Soil chemistry was found to vary significantly over short lateral distances, and it was impossible to collect samples from exactly the same spot on each sampling day. Leaching depth, as indicated by a significant increase in the concentration of calcium, magnesium, sodium and sulfate, also varied extensively over short distances. Leaching depth ranged from 0.9 to > 4.5 m. Upon comparing sites, depth of leaching was not correlated to moisture content, variation in moisture content or texture, and sites located below pivots did not exhibit greater leaching depths than sites located outside pivot circles.

DISCUSSION

Recharge below non-irrigated sites would be expected to occur during spring run-off, but the earliest 1990 moisture data was collected after this event. Based on current estimates of field capacity, significant recharge did not occur at any site between May and October. Based on a comparison of absolute moisture contents and their variation throughout the growing season, recharge was not greater below irrigated sites than below non-irrigated sites. It is possible that ponding of irrigation run-off in non-irrigated areas did increase recharge. However, run-off to low areas seems to result mainly from spring snow-melt or large precipitation events, rather than from pivot irrigation, as evidenced by the large decrease in surface moisture below non-irrigated areas after the beginning of June.

The lateral variability in leaching depth indicates that recharge rates vary significantly over short, lateral distances. Fortin et al. (1991) found that recharge on the prairies tends to be focussed below minor depressions of 1 to 2 m relief. Over short distances, greater leaching depths probably correspond to areas with larger fractures.

PRELIMINARY CONCLUSIONS

Based on current soil moisture content data, pivot irrigation does not appear to cause increased recharge below this site. A comparison of moisture contents to estimates of field capacity based on texture indicated that recharge between May and October, 1990, was minimal below irrigated and non-irrigated sites.

FUTURE WORK

Soil moisture content will be measured for one additional growing season. It will be essential to gather moisture data during spring run-off. At the beginning of the season, the neutron probe will be calibrated in the field to measure actual moisture content. The determination of characteristic curves of soil moisture retention will allow a more accurate comparison between soil moisture and the potential for recharge. The site will be surveyed on a grid system, so that moisture and chemistry data can be more closely related to minor topographic variations.

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CROP ROOTING DEPTH STUDY

Robert V. Riewe

INTRODUCTION

In 1987, a project was undertaken to study the rate and depth of root development of different crops under irrigated conditions. The project was initiated in response to a paper written by H. Borg and D. W. Grimes entitled "Depth Development of Roots With Time: An Empirical Description". In this paper, an equation was developed which calculates the rooting depth based on three variables:

1) current days after planting;
2) days to maturity;
3) maximum root development.

In 1989, this project was continued with major emphasis placed on obtaining further information for sugar beets, potatoes, sunflowers, dry beans and corn. 1989 was the third and final year for this project.

METHODOLOGY

Crops for this project were monitored on a weekly basis, with the first sampling taking place at the time of crop emergence. Monitoring of root development continued to either swathing or where the crop had matured to a point where no further root development was occurring, as determined by visual inspection. Soil/root samples were taken at 25 cm increments to a depth of 2.0 m using an Eijelkamp soil auger. Soil/root samples from each depth were visually inspected for live roots (only translucent colored roots were considered to be alive). At the time of sampling, additional notes were made on crop development, soil texture, soil moisture, weeds (density), irrigation (timing and amount), and soil physical properties (hardpans, dry layers, water tables, etc.). Crop growth was determined using the following methods:

Cereal Crops - Zadok Decimal Code (Johnston & Macleod)
Sunflowers - Description of Sunflower Stages (Schneiter & Miller)
Dry Beans - Developmental Stages of Common Bean Plant (Lebaron)
Canola - Summary of Growth Stages (Canola Growers Manual 1984)
Corn - Corn Production & Utilization in Alberta (Agdex 111/20-1)

For those crops where a guide for crop development was not available, a visual description of the crop was recorded on the day the field sampling was done.

Two soil/root sampling sites were used for each crop, with the information for the two sites being averaged. Irrigation Specialists and Irrigation Management Technologists from the Lethbridge, Taber and Vauxhall offices provided a list of names of potential farmers, from which our sampling sites were selected. Fields were selected primarily from participants on the Irrigation Management Program offered by the Irrigation Branch of Alberta Agriculture.

RESULTS

In 1989, a total of eight different crops were monitored under this project. Of these eight crops, three were corn, one was canola, eight sugar beets, four dry beans, two dry peas, three potatoes, two soft white spring wheat, and three barley fields. In total, twenty-six fields were monitored. Over the past three years (1987-1989), a total of eleven different crops and seventy-one fields have been evaluated in this project.

Due to the cool and damp spring conditions of 1989, the majority of crops were seeded late. This late seeding did have an effect on the rate of root development but not on final depth (Table 1). The number of days required to reach maximum depth did show some variation. Potatoes and soft white spring wheat showed the greatest variation in the number of days required to reach maximum rooting depth.

Borg and Grimes developed the following equation for determining crop rooting depth:

RD = RDM (0.5 + 0.5 SIN * {3.03* (DAP/DTM) - 1.47})
RD = current rooting depth (cm)
RDM = maximum rooting depth (cm)
DAP = current days after planting
DMT = days to maturity

NOTE: All calculations are to be done in radians.

Results from 1987, 1988 and 1989 indicate that the equation developed by Borg and Grimes for calculating rooting depth, estimates quite reasonably the rate and depth for potatoes, dry peas and barley (Figures 1a, 1b and 1c). This equation tends to under-estimate the rate of root development for soft wheat, canola, sugar beets, dry beans and corn (Figures 2a, 2b, 2c, 2d and 2e).

From all of the data collected to date, the rate to which roots develop follows a sigmoidal pattern. This is the same type of pattern the Borg and Grimes equation creates. The only real difference between our field results and the Borg and Grimes equation is the steepness of the curve. This change in slope seems to be the primary reason why the Borg and Grimes equation has been under-estimating rooting depth for some of the cereal, row and oil seed crops.

Based on all of the data collected, rooting depth equations have been developed for soft white spring wheat, barley, canola, dry peas, dry beans, sugar beets, corn, sunflowers and potatoes (Table 2).

Of the nine equations listing, the equation developed for corn is the only one with a limited amount of data available (one year). Coefficient of determinations (r<2) have been calculated for all of the crops. In all cases, the r<2 values exceed 0.85.

Field results have shown that the rate of root development follows a similar pattern to crop water use. As the crop enters into its critical stage of development (peak water use period), the rate of root development is at its maximum also. Once the crop begins to mature, shifting from vegetative production to reproductive growth, rate of root development begins to slow down. Maximum root depth occurs once the crop has matured. Work done by Dwyer, Stewart and Balchin found similar results with corn, soybeans and barley.

CONCLUSION

The original intent of the equation developed by H. Borg and D. W. Grimes was to create a single equation for determining crop rooting depths. Having only one equation for calculating crop rooting depths would simplify things immensely. In developing their equation, Borg and Grimes used information from 48 different crop species and 135 field observations. Days to maturity, date of seeding, and maximum rooting are the only three factors required to calculate rooting depth.

From the field data collected over the past three years, it seems that specific crop equations may be more useful and accurate in predicting crop rooting depth than the single equation developed by Borg and Grimes. With the educational approach of the Irrigation Management Program, specific crop information will be more helpful for both Irrigation Branch staff and irrigation farmers.

From all of the data collected to date, good soil moisture conditions early in the crop growing season are crucial for good root development. With the dry seed bed conditions of 1988, irrigation farmers were forced to aoply water immediately after seeding to ensure sufficient moisture was available for germination. This early irrigation allowed roots to develop sooner and at a higher rate compared to what happened in 1987 and 1989. These results indicate the importance of monitoring soil moisture conditions not only after the crop has emerged, but prior to seeding.

During the single irrigation performed by the co-operating farmer, rain gauges were installed at the site. Four sets of these gauges were located equidistance between sprinklers and the lateral sets. Each set of three gauges measured the water applied by each group of four sprinkers. This data is shown in Table 2.

TABLE 2

Zone	Sprinkler	Pressure (kPa)	Gauge	Water Depth (mm)	Average Application (mm)
1	Rainbird 30H	350	1	125	122
			2	120	
			3	122	
2	Rainbird L36A	350	1	28	34
			2	45	
			3	29	
3	Rainbird L36A	210	1	10	10
			2	10	
			3	11	
4	Nelson F33AA	210	1	19	19
			2	22	
			3	15	

It is apparent from the data that none of the alternate sprinkler/ nozzle combinations investigated by this project match or equal the performance of the "standard" Rainbird 30H @ 350 kPa (50 psi) in either radius of throw or amount of water applied.

Neither of the low pressure 210 kPa sprinklers had a wetted radius or a measured amount of water which would justify further study. The technical information required for this project was limited and misleading. The available published information only showed test results on 3.7 m risers. It appears from the limited data available here, that a low pressure sprinkler is not applicable to a wheel line application.

While the low angle (10 degree) Rainbird L36A @ 350 kPa (50 psi) did not perform up to the level of the "standard" wheel line sprinkler, it did perform measurably above the low pressure 210 kPa (30 psi) sprinklers. It applied approximately twice the measurable amount of water and had an approximately 40% longer radius of throw. There may be some potential wind fighting benefits to be realized from utilizing a "lower" (between 10 and 23 degree) angle sprinkler operating at high pressure. It is recommended that further study be done of "lower" angle sprinklers performing at normal wheel line operating pressures.

TABLE 1 - RATE & DEPTH OF ROOT DEVELOPMENT

CROP	DAILY ROOTING RATE (cm/day) (average) 1987	1988	1989	FINAL DEPTH (cm) (average) 1987	1988	1989
Canola	1.65	2.40	1.75	130	140	140
Barley	1.70	2.15	1.64	150	130	145
Sugar Beets	***	1.80	1.38	***	135	140
Dry Peas	1.40	1.70	1.25	120	110	110
Dry Beans	1.70	1.90	1.32	120	120	112
Soft Wheat	1.65	1.90	1.42	140	120	128
Sunflowers	2.30	2.15	***	160	150	***
Lentils	***	1.45*	***	***	100*	***
Potatoes	***	1.70*	1.18	***	105	120
Corn	***	***	1.49	***	***	128

* Represents only a single sampling site.
*** No samples taken.

TABLE 2 - ROOTING DEPTH EQUATIONS FOR VARIOUS CROPS

CROP	EQUATION	CORRELATION COEFFICIENT
Soft White Spring Wheat	y=27.3+(-2.7(x))+(0.1(x^2))+(-1.6E-03(x^3))+(5.4E-06(x^4))	0.91
Barley	y=11.8+(-0.6(x))+(0.1(x^2))+(-1.2E-03(x^3))+(4.5E-06(x^4))	0.91
Canola	y=40.9+(-6.5(x))+(0.3(x^2))+(-4.4E-03(x^3))+(1.9E-05(x^4))	0.90
Dry Peas	y=16.9+(-1.8(x))+(0.1(x^2))+(-1.2E-03(x^3))+(4.4E-06(x^4))	0.90
Dry Beans	y=2.8+(0.7(x))+(0.02(x^2))+(5.3E-05(x^3))+(-2.2E-06(x^4))	0.89
Sugar Beets	y=44.1+(-4.2(x))+(0.2(x^2))+(-1.5E-03(x^3))+(4.3E-06(x^4))	0.93
Sunflowers	y=16.2+(2.7(x))+(-6.04(x^2))+(1.6E-03(x^3))+(-1.1E-05(x^4))	0.89
Corn	y=19.8+(-0.3(x))+(-0.0038(x^2))+(7.0E-04(x^3))+(-5.2E-06(x^4))	0.95
Potatoes	y=172.1+(-10.9(x))+(0.3(x^2))-(-2.1E-03(x^3))+(5.9E-06(x^4))	0.88

y = rooting depth (cm) x = days after planting

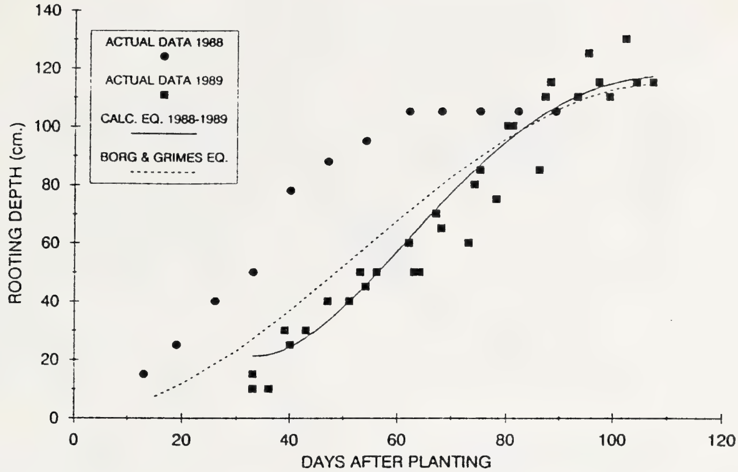

Figure #1a. Rooting Depth vs. Time for Potatoes.

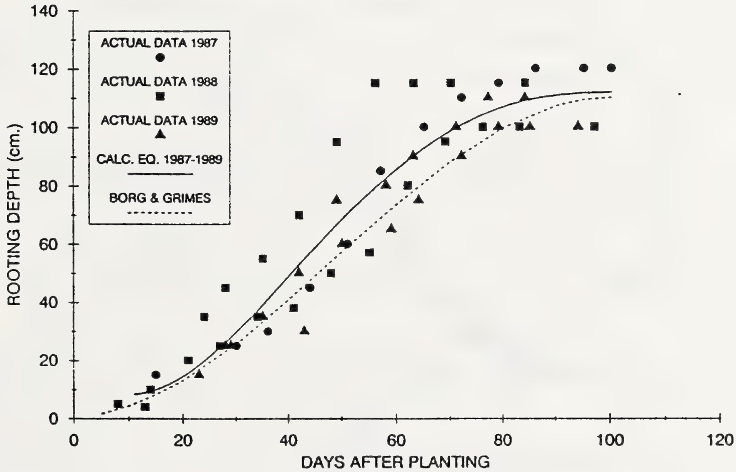

Figure #1b. Rooting Depth vs. Time for Dry peas

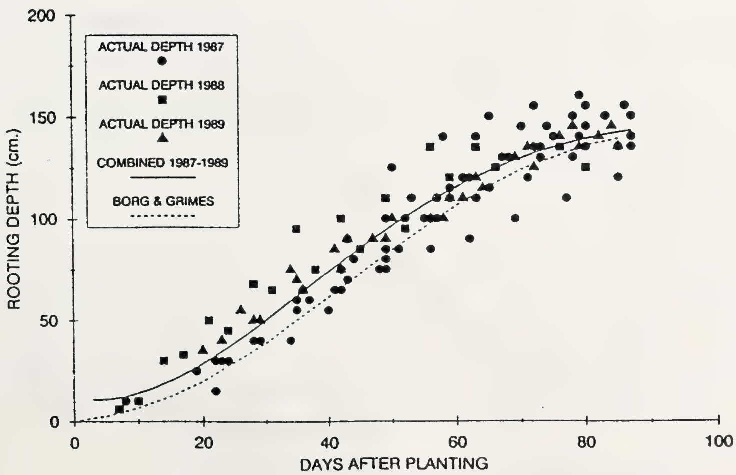

Figure #1c. Rooting Depth vs. Time for Barley.

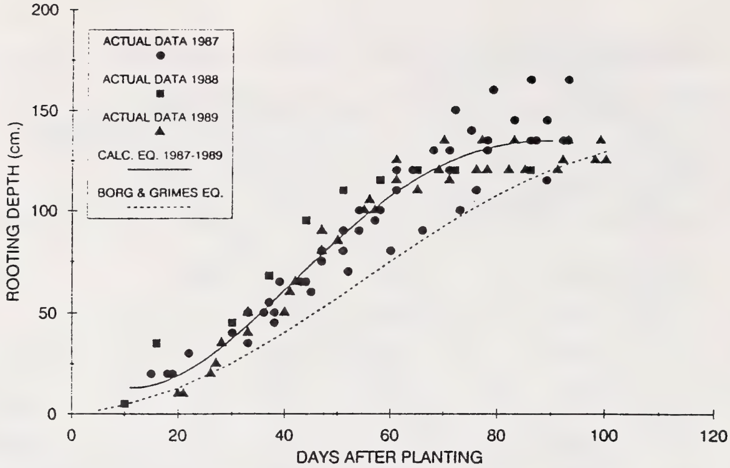

Figure #2a. Rooting Depth vs. Time for Soft Wheat.

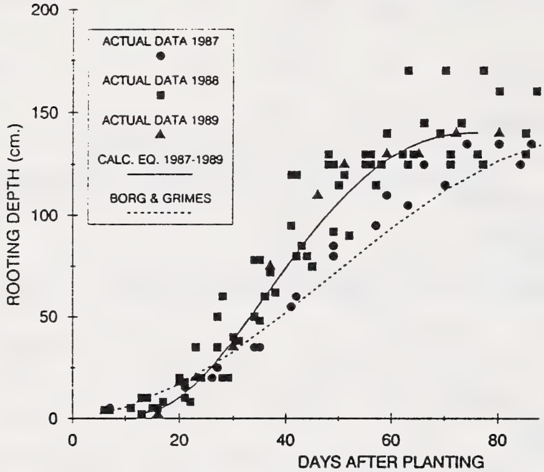

Figure #2b. Rooting Depth vs. Time for Canola.

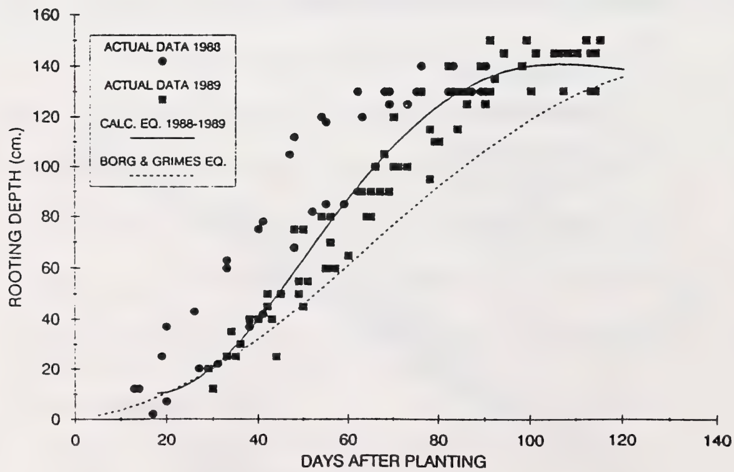

Figure #2c. Rooting Depth vs. Time for Sugar Beets.

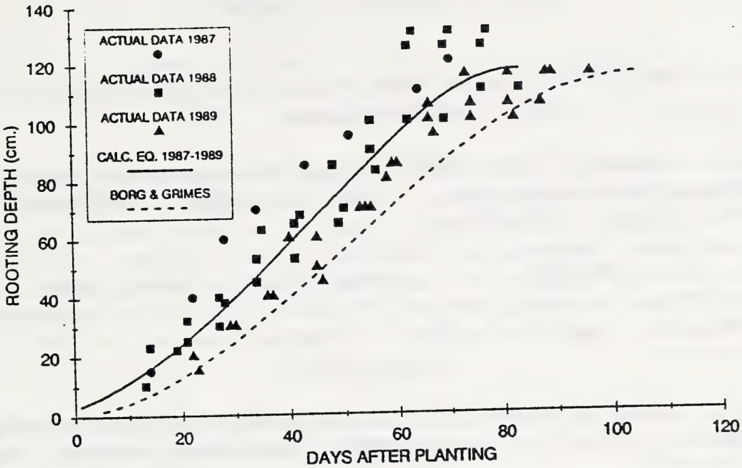

Figure #2d. Rooting Depth vs. Time for Dry Beans.

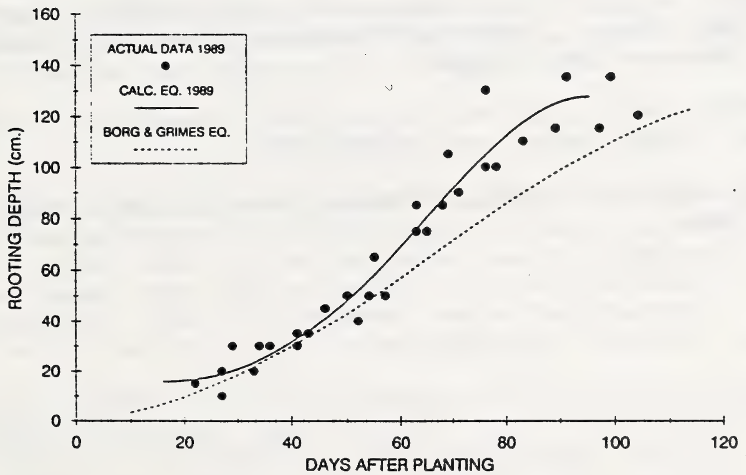

Figure #2e. Rooting Depth vs. Time for Corn.

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CORRELATION OF SUGAR CONTENT IN SUGAR BEETS TO TIMING OF IRRIGATION WATER

R. Riewe, G. Cook, V. Ellert, R. Collett '

INTRODUCTION

A survey was undertaken in 1990 to determine the effect the timing of irrigation water has on sugar content. Information from the survey was to be used to create new crop water use versus yield curves for sugar beets. At the same time, present day irrigation management practices were to be evaluated to determine the best possible irrigation schedules for maximum sugar production

METHODOLOGY

With the assistance of the Alberta Sugar Beet Growers Association, 19 farmers and 47 fields were used in this survey.

On a weekly basis, soil moisture was determined for each field. The "feel method" was used for this determination. Periodically, gravimetric samples were taken to adjust soil moisture values. Soil moisture samples were taken at 25 cm increments to a depth of 1.0 m.

Prior to the fields being monitored, each field was inspected and appropriate soil moisture monitoring sites were selected. Irrigation and rainfall information was collected on a weekly basis from the irrigation farmer.

RESULTS

From the information collected from the survey, no definite correlation exists between the total amount of sugar produced (% sugar x tonnage) and weeks above 50% of available moisture (Figures 1a and 1b). Davidoff and Hanks found similar results in that the level of irrigation had no consistent effect on sucrose levels for harvest. Method of irrigation had no bearing on total sugar production or percent sugar.

Of the 47 fields monitored on this project, only 34% exceeded both the factory average for percent sugar and total sugar yield (Figure 2). 36% of the fields exceeded the factory average for percent sugar and 79% (or 37 fields) exceeded the factory average for total sugar produced. Of the 37 fields that exceeded the factory average for total sugar produced, 57% had total percent sugar values that were lower than the factory average. This high value of total sugar produced indicates that sugar beet growers are still striving to produce high tonnage.

Figure 3 may be an indicator on the amount of reduction that may occur if sugar beets are harvested too early. 55% of the fields were harvested during the time period of Julian day 280-290 (October 7 to 17).

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Of the group of fields harvested during this time period, 35% were above the factory average for percent sugar (Figure 3a) and 73% were above the factory average for total sugar produced (Figure 3b). There were only six (13%) of the fields harvested before October 7. Of these fields, only one was above the factory average for percent sugar and total sugar produced.

Crop consumptive use varied from a low of 323 mm to a high of 565 mm. Tonnes of sugar beets produced ranged from a low of 13.0 to a high of 23.29. Figure 4 compares the crop water use vs. crop yield for all fields monitored. The field with the lowest crop consumptive use exceeded the factory averages for both percent sugar and total sugar produced (Field L, Figure 2). Because of poor record keeping by the farmer, more irrigation water may have been applied than what was actually recorded.

The crop with the highest crop consumptive use slightly exceeded the factory average for total sugar produced, but was well below the factory average for percent sugar (Field H, Figure 2). Only 25% of the fields monitored met the water requirements of the crop, as outlined in the Irrigation Management Handbook. 15% of the fields met 82% of the crop water requirement and 34% of the fields met 72% of the crop water requirements (Figure 5). From this, it is apparent that irrigation farmers continue to under-irrigate their crops.

It is recommended that the last irrigation on sugar beets occur the last week of August to the first week in September. Ceasing irrigation at this time would allow the root zone to dry down sufficiently for digging purposes. By stressing the crop, percent sugar content is increased. Over-watering late in the growing season causes sugar beets to retain moisture, increasing tonnage but not dry matter, thus decreasing percent sugar. At the time of harvest, 57% of the fields monitored had soil moisture conditions greater than 60% available moisture. Of this group, 67% exceeded the factory average for total sugar produced. Of those fields which had available soil moisture levels less than 60%, 53% exceeded the factory average for total sugar produced.

CONCLUSION

At the present time, sugar beet growers continue to strive to produce the maximum tonnage. Even though Alberta Sugar now pays sugar beet growers based on percent sugar, beet growers still are able to make a profit in raising sugar beets by striving for high tonnage.

Good management of all input factors is required to obtain both high percent sugar content and high total sugar produced per acre. Fertilization, plant populations, weed control, seed bed preparation, are only a few of the factors that affect sugar beet production. Irrigation plays a major role in reaching the goal of high percent sugar and total sugar produced. As the direction of Alberta Sugar changes from strictly tonnage-oriented production to a combination of percent sugar content and total impurities present, sugar beet growers will have to change their management practices to meet these new requirements.

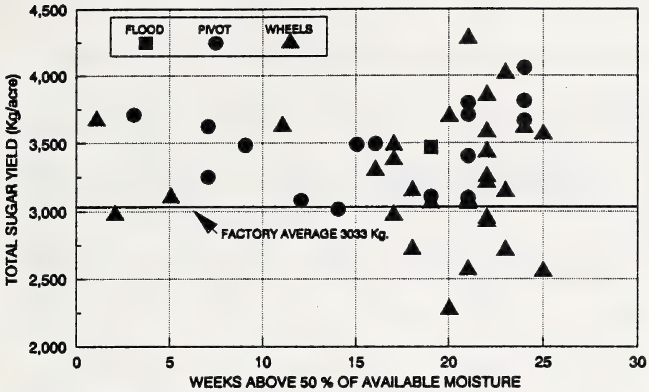

FIGURE 1a: WEEKS ABOVE 50% OF A.M. vs. TOTAL SUGAR YIELD
1990 SUGAR CONTENT STUDY

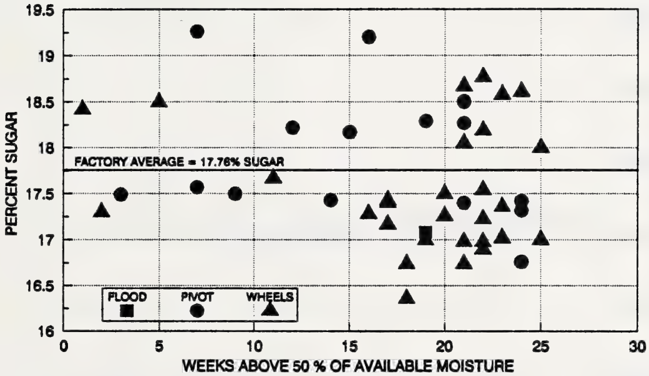

FIGURE 1b: WEEKS ABOVE 50% OF A.M. vs. PERCENT SUGAR
1990 SUGAR CONTENT STUDY

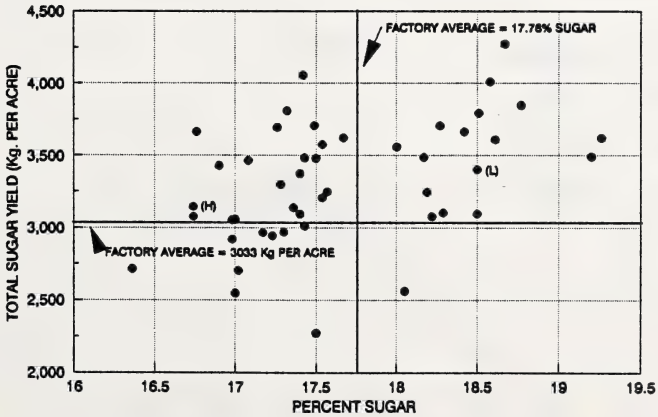

FIGURE 2: PERCENT SUGAR vs. KG. SUGAR PER ACRE
1990 SUGAR CONTENT STUDY

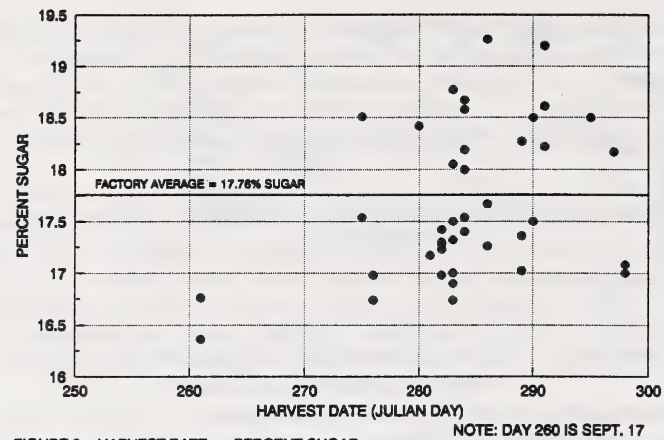

FIGURE 3a: HARVEST DATE vs. PERCENT SUGAR
1990 SUGAR CONTENT STUDY

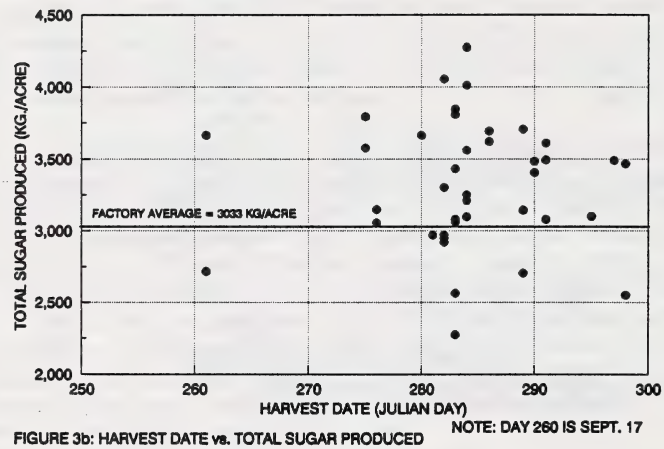

FIGURE 3b: HARVEST DATE vs. TOTAL SUGAR PRODUCED
1990 SUGAR CONTENT STUDY

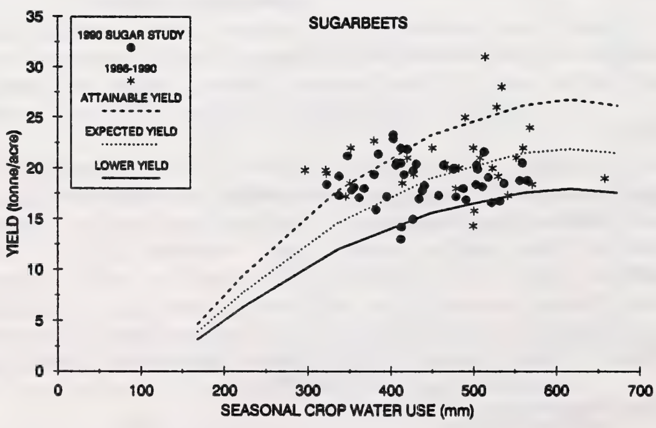

FIGURE 4: CROP WATER USE vs. CROP YIELD

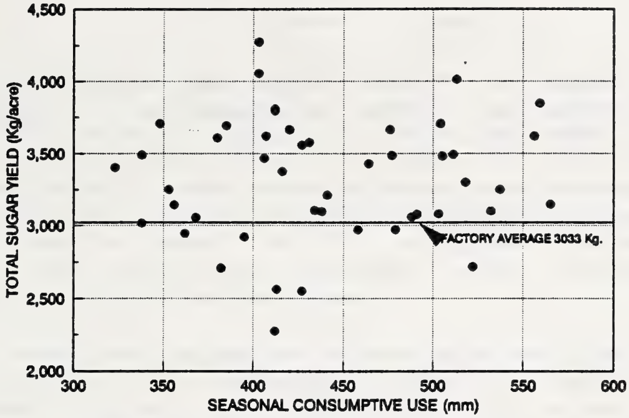

FIGURE 5: SEASONAL CONSUMPTIVE USE vs. TOTAL SUGAR YIELD
1990 SUGAR CONTENT STUDY

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THE INFLUENCE TIMING OF IRRIGATION WATER HAS ON CROP YIELD

Robert V. Riewe

INTRODUCTION

Since 1985, water rationing or sharing has been a dilemma which both irrigation districts and irrigation farmers have had to face. 1986 and 1988 were two years in which water rationing was implemented. The cause of water rationing has been due to the open winters (limited snow pack in the mountains), limiting runoff to fill irrigation reservoirs. With water becoming an ever more scarce resource, water management by irrigation farmers will become even more critical.

In the past, most irrigation farmers were not primarily concerned with the amount of water that was needed to meet crop water demand, but rather were concerned with the timing of their next irrigation. Since both timing and amount of water applied are important, this project was developed to demonstrate the effect various water application schedules had on crop production. Plant growth, soil moisture, and time of year are the three (3) main factors on which irrigation farmers base their irrigation scheduling. These three factors were used in creating the 12 different irrigation schedules for this project. Figure 1 outlines these various schedules.

This Farming For the Future Demonstration Project was located 6.5 km north of the hamlet of Chin, Alberta.

PROJECT DESIGN

The project area was cultivated, fertilized, and seeded by the co-operating farmer. During the previous growing season (1988) the project site had been fertilized but due to the dry seed bed conditions no crop was seeded. In the spring of 1989, 125 lbs./ac. of actual N, 40 lb./ac. of actual P, and 12.5 lb./ac. of actual S was applied using an air seeder. Sceptre Duram Wheat was seeded at 2 bu./acre on May 16. Buctril M herbicide was applied according to manufacturer's recommendations on June 22, 1989 to control a wide range of broad leaf weeds.

The project utilized a randomized block design. The size of each plot was 20' x 20' (6.1 M x 6.1 M) with a 30' (9.1 M) buffer zone between each plot (N-S axis) as shown in Figure 2. Each treatment was replicated three times. Total project size was 3.03 acres (1.2 ha.).

A solid set irrigation system was used consisting of 2" aluminum laterals and 3" aluminum mainline. Water was pumped from a dugout located adjacent to the plots using a gasoline powered pumping unit. Sprinklers with individual manual shut-off valves were located on risers at the corners of each plot. This allowed for uniform water application within the plot along with independent irrigation of each plot.

Rainfall was measured by means of a Tru-chek rain gauge located just outside the project area. Air temperature, solar radiation, and wind

travel information was obtained on a weekly basis from Agriculture Canada at Lethbridge.

Soil moisture measurements (using a Troxler Nuclear Moisture Gauge) were taken at 25 cm intervals to a depth of 125 cm. Aluminum access tubes (1.2 m in length) were installed in each of the thirty-six plots. Soil moisture was measured on a weekly basis from the time the crop germinated to harvest. A 48 hour delay in taking soil moisture readings was allowed after an irrigation or heavy rainfall. This was to ensure that all of the water applied to the soil had infiltrated.

Yield sampling consisted of three one-metre square samples taken randomly throughout each plot area. Individual plots were cut by hand with samples put into burlap bags for air drying. A Kincaid Belt Threshing Machine was used to thresh the crop samples when they reached a moisture content of approximately 15%. These grain samples were then cleaned using a Blount/Ferrell-Ross Cleaner. The cleaned grain samples were then weighed for yield determination.

RESULTS AND DISCUSSION

Regardless of the method used to determine the when to irrigate, the critical factor is that the crop requires a good supply of water the entire crop growing season. Yield and consumptive use results obtained in 1989 (Table 1) showed that irrigating at the 50% depletion level (treatment A) commencing at the 3 leaf stage (treatment I), or irrigating up to July 30 (treatment H) were almost identical. (Note: The Irrigation Management Program presently uses the 50% depletion level as a guide for determining an irrigation farmer's timing schedule). Maintaining soil moisture levels greater than the 50% level, as was done in treatment B, has only limited benefits. The increase in yield for treatment B is only 6% (5.2 bu/acre) higher than treatment A (the check). The irrigation requirements (Table 2) for treatment B are 32% (63 mm) greater than the check. Irrigating at the 75% depletion (treatment C) gave a reduction in yield of 18% (13.3 bu/acre) compared to the check. The results obtained are similar to the findings of Hobbs and Krogman, Heywood, and McKenzie.

Where water supplies for irrigation are limited, irrigation farmers should look seriously at crops which have low seasonal water requirements. Preliminary results indicate that a reduction in yield of 25% can be expected if irrigation ceases at the end of June, and a reduction in yield of 11% if irrigations are terminated July 15.

Commencing an irrigation based solely on a certain stage of crop growth is not recommended. Delaying the first irrigation to either the flag leaf stage or after the application of herbicides, crop yields can be reduced by 21% and 16% respectively. One large application of water at the heading out stage will reduce crop yield by 34%.

FIGURE 1 - DESCRIPTION OF DIFFERENT IRRIGATION TREATMENTS

A. Maintain 50% of available moisture. Irrigation started when 50% of the avalable moisture in the root zone has been depleted. This is the normal recommendation for cereal crops.

B. Maintain 75% of available moisture. Irrigation started when 25% of the available moisture in the root zone has been depleted. This is a "wetter than normal" treatment.

C. Maintain 25% of available moisture. Irrigation started when 75% of the available moisture in the root zone has been depleted. This is a "dryer than normal" treatment.

D. Commence irrigation after spraying. Once irrigation takes place, soil moisture will be maintained at 50% of available moisture until harvest.

E. Maintain 50% of available moisture in top 50 cm of root zone only.

F. Maintain 50% of available moisture until cut-off date of June 30.

G. Maintain 50% of available moisture until cut-off date of July 15.

H. Maintain 50% of available moisture until cut-off date of July 31.

I. Commence irrigation at th 3 leaf stage. Soil moisture maintained at 50% of available moisture thereafter.

J. Commence irrigation when flag leaf just visible. Soil moisture maintained at 50% of available moisture thereafter.

K. Commence irrigation when emergence of head completed. (This represents an irrigation at the critical stage of growth only). Soil moisture maintained at 50% of available moisture thereafter.

L. Dryland or rainfed.

(NOTE: All irrigations will cease when root zone is at field capacity).

TABLE 1 - CONSUMPTIVE USE & CROP YIELD RESULTS

PLOT	CROP CONSUMPTIVE USE	YIELD (bu/acre)
A	350	85.2
B	433	90.4
C	309	69.9
D	303	72.1
E	269	92.4
F	253	63.4
G	298	76.2
H	340	85.3
I	381	84.0
J	310	67.5
K	308	56.4
L	186	42.7

TABLE 2 - IRRIGATION WATER APPLIED

PLOT	IRRIGATION WATER APPLIED (mm)
A	196
B	259
C	85
D	112
E	151
F	47
G	98
H	149
I	192
J	101
K	95
L	0

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EVALUATION OF ALTERNATE SPRINKLERS FOR SIDEROLL IRRIGATION SYSTEMS

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INTRODUCTION

Approximately 162,000 ha. of land are irrigated by sideroll irrigation systems in southern Alberta. Any improvement in the application efficiency of these systems could result in a considerable saving of water. Improvements in application efficiency are most likely to result from a reduction in the wind drift.

In the past ten years, there have been several new designs of sprinklers applied to centre pivots. These new designs have been successful in reducing wind drift and operating pressures. The sprinklers used on sideroll systems have remained unchanged since their introduction 30 years ago.

Recently, sprinkler manufacturers have introduced several new designs of 3/4 inch sprinklers that may be applicable to sideroll irrigation systems. These designs have the potential of reducing wind drift and operating pressures. Farmers are reluctant to use the newer sprinklers (technology) until they have been proven to be effective in reducing water losses due to wind drift.

METHOD

Four types of sprinkler/nozzle combinations were installed on a sideroll irrigation system. Each set of sprinklers consisted of four identical sprinkers in a group. The types of sprinklers and nozzles tested were:

a) standard 23 degree trajectory sprinklers with straight bore nozzles operating at 350 kPa (50 psi).

b) 10 degree trajectory sprinklers with straight bore nozzles operating at 350 kPa (50 psi). Rainbird L36A with QF-SB-3 nozzles.

c) 10 degree trajectory sprinklers with low pressure nozzles operating at 210 kPa (30 psi). Rainbird L36A with QF-LP-3 nozzles.

d) 15 degree trajectory sprinklers with flow control diffuser nozzles operating at 210 kPa (30 psi). Nelson F33AA with F.C. diffuser nozzles.

To ensure the correct operating pressure of each sprinkler, a pressure regulator was installed at the base of each sprinkler tested.

Soil moisture was measured on a weekly basis using a Troxler 3222 soil moisture probe. Soil moisture measurements were taken at 25 cm increments to a depth of 1 m.

Five aluminum access tubes were installed within the sample area of each group of sprinklers. Refer to "Sample Area Detail" within Figure 1. At the time of access tube installation, one set of soil samples was kept for each nest. Particle analysis was determined for each set of soil samples taken using the Hydrometer Method.

Climatic information (rainfall, wind travel, air temperature, and solar radiation) was recorded daily.

Timing of irrigation and amount of water applied was to be obtained from the farmer. Catch cans were to be used to measure the amount of water applied by the irrigation farmer. A pitot tube with a gauge was to be used to measure the operating pressure of the irrigation system.

RESULTS AND DISCUSSION

The sideroll irrigation system used for this project was located adjacent to the Town of Coaldale, Alberta.

Due to unforeseen circumstances, this project was discontinued at the end of June at the request of the irrigation farmer. Factors leading to the discontinuation of this project were:

1) limited irrigation by the co-operating farmer;
2) visual operations of the sprinkers.

Information obtained while the side wheel roll irrigation system was in operation indicated that none of the non-standard sprinklers (Rainbird L36A with QF-SB-3 nozzle, Rainbird L36A with QR-LP-3 nozzle, and Nelson F33AA with F.C. diffuser) had the required diameter of throw for a suitable application rate (Table 1).

TABLE 1 - ALTERNATE SPRINKLERS
(Wetted Radius Measurements)

Zone	Sprinkler	Trajectory (Degrees)	Nozzle	Pressure (kPa)	Radius (M)
1	Rainbird 30H	23	Straight bore	350	15.2
2	Rainbird L36A	10	QF-SB-3	350	10.7
3	Rainbird L36A	10	QR-LP-3	210	7.8
4	Nelson F33AA	15	F.C. Diffuser	210	8.1

NOTE: F.C. = Flow Control

In order to obtain uniform coverage of a field, the overlap between sprinkler sets is critical. The study shows that the lower pressure sprinklers are not capable of producing sufficient overlap. A minimum radius of 13.7 m (45 feet) is required for sufficient overlap between sprinkler heads.

During the single irrigation performed by the co-operating farmer, rain gauges were installed at the site. Four sets of these gauges were located equidistance between sprinklers and the lateral sets. Each set of three gauges measured the water applied by each group of four sprinkers. This data is shown in Table 2.

TABLE 2

Zone	Sprinkler	Pressure (kPa)	Gauge	Water Depth (mm)	Average Application (mm)
1	Rainbird 30H	350	1	125	122
			2	120	
			3	122	
2	Rainbird L36A	350	1	28	34
			2	45	
			3	29	
3	Rainbird L36A	210	1	10	10
			2	10	
			3	11	
4	Nelson F33AA	210	1	19	19
			2	22	
			3	15	

It is apparent from the data that none of the alternate sprinkler/ nozzle combinations investigated by this project match or equal the performance of the "standard" Rainbird 30H @ 350 kPa (50 psi) in either radius of throw or amount of water applied.

Neither of the low pressure 210 kPa sprinklers had a wetted radius or a measured amount of water which would justify further study. The technical information required for this project was limited and misleading. The available published information only showed test results on 3.7 m risers. It appears from the limited data available here, that a low pressure sprinkler is not applicable to a wheel line application.

While the low angle (10 degree) Rainbird L36A @ 350 kPa (50 psi) did not perform up to the level of the "standard" wheel line sprinkler, it did perform measurably above the low pressure 210 kPa (30 psi) sprinklers. It applied approximately twice the measurable amount of water and had an approximately 40% longer radius of throw. There may be some potential wind fighting benefits to be realized from utilizing a "lower" (between 10 and 23 degree) angle sprinkler operating at high pressure. It is recommended that further study be done of "lower" angle sprinklers performing at normal wheel line operating pressures.

THE EFFECTS OF IRRIGATION ON TWO CULTIVARS OF LENTILS

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The effect of irrigation on yield, quality and maturation of the seed of two types of lentils was measured in a rates-of-irrigation experiment. This year, 1989, was the third year of this experiment. Laboratory analysis of soil and plant samples was provided by Alberta Agriculture's Soils and Animal Nutrition Laboratory, Edmonton, and Alberta Agriculture's Land Classification Laboratory, Edmonton.

Materials and Methods

Two cultivars of lentils were grown under four levels of irrigation: Laird, a late maturing variety with large seeds, and Eston, an early-maturing variety with small seeds. They were seeded on May 17--Eston at 42 kg/ha and Laird at 100 kg/ha.

Results from analyses of soil samples taken prior to seeding, are reported in Tables 1, 2, and 3. Fertilizer was applied at 75 kg/ha of 12-51-0 with the seed. Ethalflurin, a pre-emergent weed control chemical, was incorporated into the soil prior to seeding. The treatment areas were hand weeded. The guard areas were mowed in June and disced in early August to control the Canada thistle and volunteer grain.

Table 1. Fertility analyses (in ppm) of the soil from the lentil plot site.

Depth (m)	K	P	NO_3-N	NH_4-N	SO_4-S
0.00-0.15	310	34.3	3.8	4.5	8.8
0.15-0.30	130	3.5	8.5	4.3	6.0
0.30-0.60	105	0.3	7.3	3.8	5.0
0.60-0.90	108	0	2.0	3.0	10.3
0.90-1.20	145	0.8	0.5	4.3	23.4

Table 2. Chemical and particle size analysis of soil from the lentil plot site

Depth (m)	EC	pH	SAR	Na mnol/S	Texture	% S	% Si	% C
0.0-0.30	2.0	7.3	1.4	4.4	SL	65	19	17
0.30-0.60	2.9	7.5	3.1	11.2	SL SCL	60	20	20
0.60-0.90	4.0	7.7	5.7	22.0	L	47	28	26
0.90-1.20	4.8	7.9	8.2	30.7	CL	44	26	31
1.20-1.50	6.6	7.8	10.5	47.5	CL	42	28	31

The experiment consisted of four water treatments, labelled W0, W1, W2, and W3, and four replicates. Available water holding capacity for the plot site is reported in Table 3. The

water treatments consisted of plots 7.6 x 7.6 m with guard areas of 10.7 m between water treatments. Water treatments vared from no irrigation on W0 to a number of small irrigations on W3 to keep the available moisture above 70% field capacity. The other treatments were W1 which received one large irrigation in mid-season, and W2 which received two large irrigations during the season. Since the seedbed was dry at seeding, all treatments received a small irrigation after seeding to ensure germination of the seed.

Table 3. Bulk density (DB), field capacity (FC), permanent wilting point (PWP), and available soil water holding capacity (AWHC) of the lentil plot site

Depth	DB	FC %	PWP %	AWHC (mm)
0.0-0.30	1.53	17	6	51
0.30-0.60	1.51	18	7	51
0.60-0.90	1.48	21	9	54
0.90-1.20	1.45	22	10	53
1.20-1.50	1.47	21	9	53

Results and Discussion

Soil moisture records were kept over the season for a root zone of 0.9 m. Initial and final moisture samples were taken to 1.5 m and these, along with amounts of irrigations and rainfall, were used to determine consumptive use of water.

Table 4. Rainfall, irrigation, soil moisture depletion and consumptive use for two varieties of lentils

Irrigation treatment	Rainfall (mm)		Irrigation (mm)	Depletion (mm)		Consumptive Use (mm)	
	Eston	Laird		Eston	Laird	Eston	Laird
W0	59.3	79.9	24.0	137	140	220	244
W1	64.3	87.7	69.8	123	114	257	272
W2	67.3	89.8	74.3	115	108	257	272
W3	99.3	99.3	151.8	79	76	330	327

The depletion of available water was inversely related to the amount of irrigation provided. This reduced differences in consumptive use between different irrigation treatments. Rainfall is different between treatments because of different harvest dates (Table 4).

Seed and straw yields are reported in Table 5. In 1989 there was no significant difference in seed yield between irrigation treatments of Eston. With Laird the treatments W2 yielded significantly more seed than W0 and W3 and treatment W1 yielded significantly more than W0.

Seed protein content (Table 5) was not significantly influenced by irrigation in 1989. This is similar to 1988 where there was also no influence of irrigation treatment on protein content. The cultivar Eston had a slightly higher protein content than Laird. It is important that with a legume such as lentils, protein content does not decline in the manner it does with frequent irrigation of non-legume such as wheat or canola.

Straw yields were higher for Laird than Eston and both cultivars had significantly higher straw yields on W3 than on the other treatments.

Fig 1 and 2 show the relationship between yield and water use for 3 years for Eston and Laird lentils. Laird, a cultivar with indeterminate growth habit, achieved a maximum yield at a water use of from 260 to 300 mm. (When the water use was higher the seed yield declined and forage yield increased.) Eston, a determinate growth habit cultivar, achieved a maximum seed yield at about 260-300 mm water use in 1987 and 1989. In 1988 at a site surrounded by unirrigated fallow and crop the highest yield was achieved at a water use of 380 mm. Transpiration would normally be much higher under these circumstances than in an area surrounded by irrigated crops. Lentils appear to yield highest at a water use which is about 70% of that of most other crops. An indeterminate cultivar like Laird is very sensitive to overwatering.

Table 5. Seed, straw yield, and seed protein content of two cultivars of lentils grown at four levels of irrigation

	Seed yield (kg/ha)		Straw yield (t/ha)		Seed % protein⁺	
	Eston	Laird	Eston	Laird	Eston	Laird
W0	1897	1988	2.08	2.93	24.8	24.1
W1	2517	2342	2.57	3.03	25.4	24.2
W2	2364	2422	2.23	2.75	25.6	24.1
W3	2363	1674	3.80	4.12	26.8	23.7
LSD♦		433	0.64	0.88		
F	1.9	5.9*	12.7**	4.8*	2.4	0.4

⁺% protein determined at 14% moisture.
♦LSD (Waller and Duncan 1969) at the 100:1 error serious ratio (analagous to 5% level)
*F value significant at the 5% level
**F value significant at the 1% level

Fig. 1 Yield in kg/ha and water use in mm of Eston lentils from 3 years irrigation experiments.

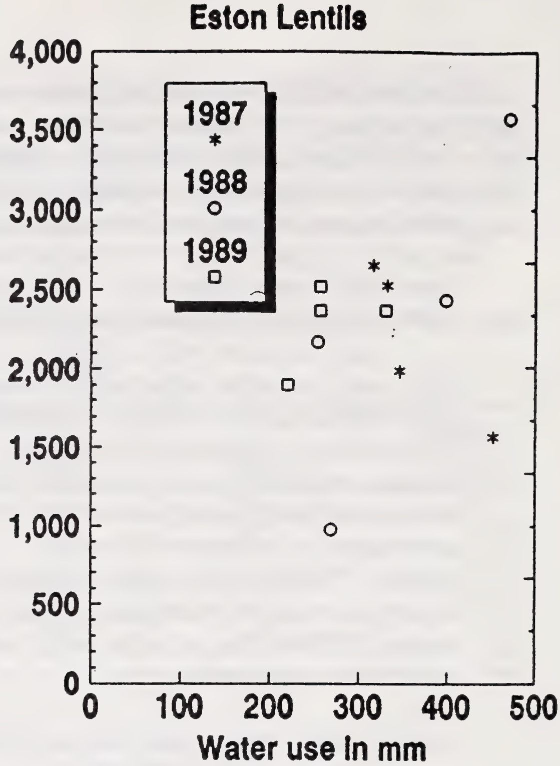
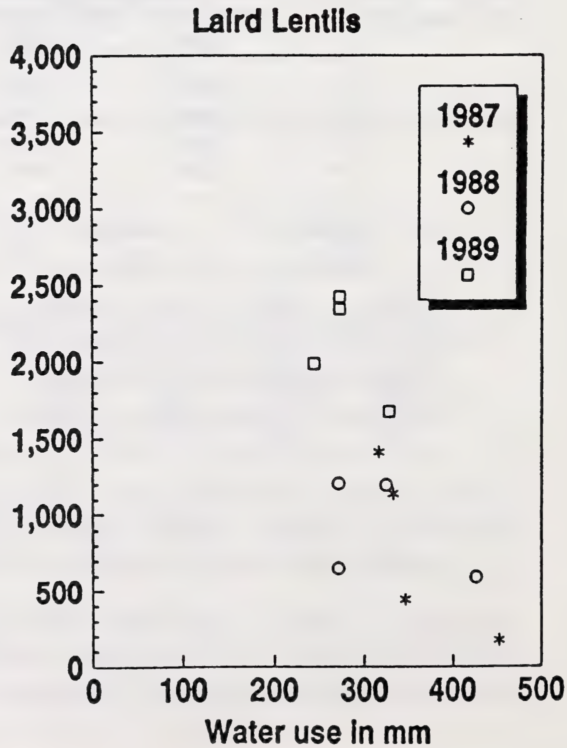


Fig. 2 Yield in kg/ha and water use in mm of Laird lentils from 3 years irrigation experiments.



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LEACHING OF A HIGHLY SALINE-SODIC SOIL IN SOUTHERN ALBERTA: A FIELD STUDY

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INTRODUCTION

Reclamation of saline soils first requires the disconnection, or control, of the upward migration of salts from groundwater into the soil. On irrigated land this is usually accomplished with subsurface drainage. The second requisite is the leaching of salts by applying excess irrigation water (Rhoades 1982).

Hoffman (1980) gives the following simple equation to estimate the extent of salt removal from a soil when leaching water is applied:

$$(C/Co)(dl/ds)=k$$

where Co and C are the initial salt concentration and the salt concentration at some point in time during leaching, respectively, dl and ds are the depth of leaching water and depth of soil, respectively, and k is an empirical constant, which usually ranges from 0.1 to 0.3 depending upon soil type and irrigation method. Harker and Mikalson (1990) leached a highly saline-sodic soil from southern Alberta in the laboratory. They found that the empirical constant, k, ranged from 0.17 to 0.37 but averaged about 0.25. Because this was a laboratory study factors which affect the efficiency of the leaching process in the field were not assessed. Field factors would include capillary rise of saline groundwater, evapotranspiration, runoff and seasonal resalinization. The present study was conducted to determine the influence of these latter factors on the leaching process and their influence on the empirical constant k.

MATERIALS AND METHODS

The site used for this study was the same saline seep where Harker and Mikalson (1990) sampled their soil cores. A 0.25-ha area was subsurface drained at a 1.2-m depth and 12.5-m spacing. Six sampling locations were established in the seep in a gradient from upslope to midslope to lower slope positions, with two sampling locations per seep position. This gave a gradient in salinity, water-table depth and groundwater discharge. Four-electrode salinity sensors were constructed according to the method of Rhoades (1979) except stainless steel was used for the electrodes, rather than copper, to prevent corrosion. All four-electrode sensors were calibrated against solutions of known salinity using a commercial four-electrode cell. Calibrated sensors were installed at the midpoint of depth increments of 0-15, 15-30, 30-60 and 60-90 cm.

Sprinkler irrigation was conducted for three years (1986-1988), and was usually performed two or three days each week from June to October.

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Salinity sensors were read on the day following cessation of irrigation (usually 18 hr. after stopping irrigation). In this way the moisture content was relatively uniform between readings on different dates and thus sensor readings would mainly reflect differences in salinity. All sensor readings were temperature corrected to 25°C.

Class A Pan evaporation was measured on site and was converted to potential evapotranspiration (ETp) using pan coefficients of Doorenbos and Pruitt (1977). Rainfall was recorded using a rain gauge. Water applications by irrigation were determined using a 1.2-m diameter calibrated pan. Runoff measurements were occasionally determined for the different sampling locations using shallow ditches and 90° v-notch weirs.

RESULTS AND DISCUSSION

Fig. 1 gives the minimum, maximum and average leaching curves, based on net water applications (gross water applied less ETp), which were encountered in this study. The average curve of Harker and

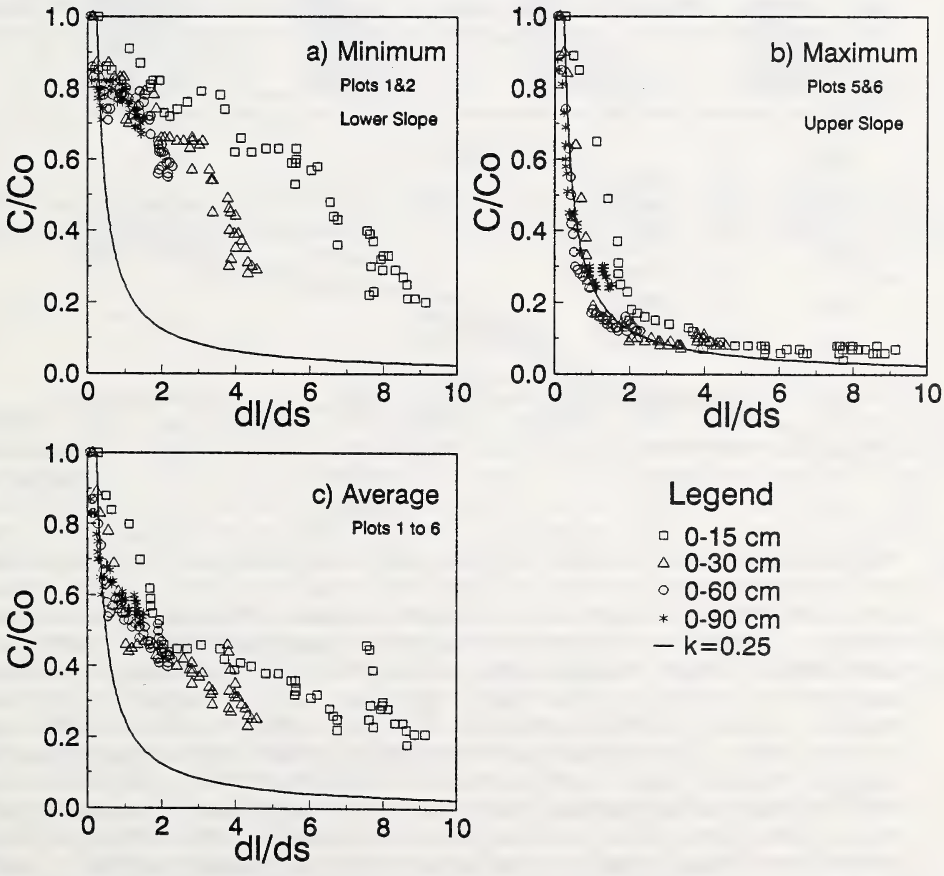

Fig. 1 Relative salinity reduction (C/Co) versus relative depth of leaching water (dl/ds) for a) minimum leaching, b) maximum leaching and c) average leaching. Value for dl is ETp corrected.

Mikalson (1990), where k=0.25, is given for comparison. The minimum leaching (average of two sampling locations, n=2) occurred at the lower slope position (Fig. 1a) where groundwater discharge gradients were observed and runoff occurred during irrigation. The maximum leaching (n=2) occurred at the upper slope position (Fig. 1b) where groundwater gradients were mostly lateral and runoff was not observed. Leaching at the midslope position, not shown, was similar to that observed at the lower slope position. The average k factors, for net water application for all soil depths, were 1.28, 0.31 and 0.93 for the minimum, maximum and average leaching curves, respectively. For the plots where maximum leaching occurred (Fig. 1b) the k factor of 0.31 is similar to that observed by Harker and Mikalson (1990).

During the study k was found to gradually increase with time at most plots (Fig. 2) which suggests the efficiency of leaching decreased with time. This is thought to occur (at least when soils are continuously ponded) because initially salts are rapidly leached from the large conducting pores and subsequent removal of salt from the matrix of the soil is slower (Hoffman 1980). This was not expected to occur under sprinkler irrigation because salts could diffuse from the matrix to conducting pores between irrigation events. It is likely that the frequent irrigation and shallow water table promoted wet conditions and this restricted salt migration from the matrix material (Hoffman 1980).

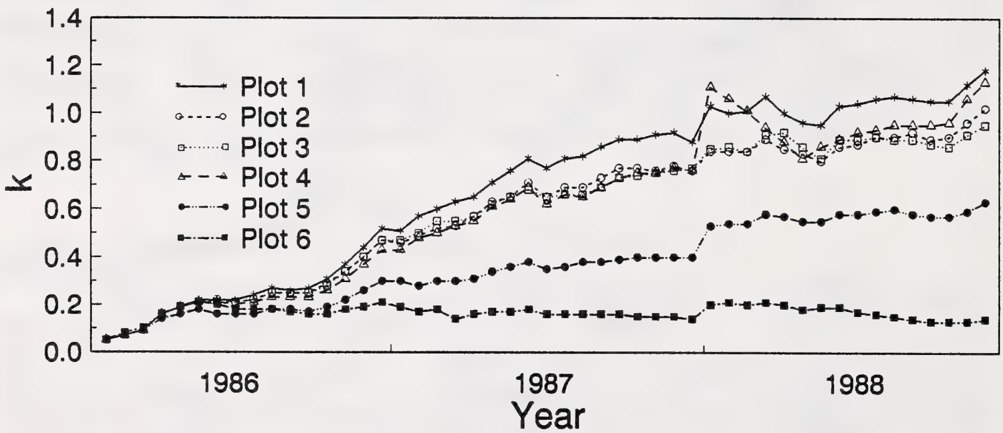

Fig. 2 Calculated values for the empirical constant, k, over time.

The leaching constant, k, also varied according to the correction used to determine the amount of water passing through the soil (i.e. that water which contributed to leaching). The farmer will usually measure or estimate gross water applied, and as shown in Fig. 3, this results in the highest constant k to be used in the leaching equation. If net water (corrected for ETp only) is used then the value of k is roughly halved (pan coefficients in this study were about 0.5 and thus half of the water applied contributed to leaching, the remaining half to Etp). When net water applied is calculated by considering both ETp and overwinter resalinization the value for k decreases further. Accounting for ETp and runoff further reduces k. Correction for ETp, overwinter resalinization and runoff results in the lowest average value of k. The "fully" corrected value for k for all plots, all times and all depths

was 0.27, which is in excellent agreement with findings of Harker and Mikalson (1990).

Fig. 3 also illustrates that k decreased as the depth of soil through which the water passed increased, indicating the leaching process was more efficient at greater soil depths. This probably occurred because evaporation driven processes, such as the upward migration of salts, are strongest near the soil surface (Gardner 1958). The "fully" corrected values for k were 0.46, 0.29, 0.19 and 0.18, respectively, for soil depths of 0-15, 0-30, 0-60 and 0-90 cm.

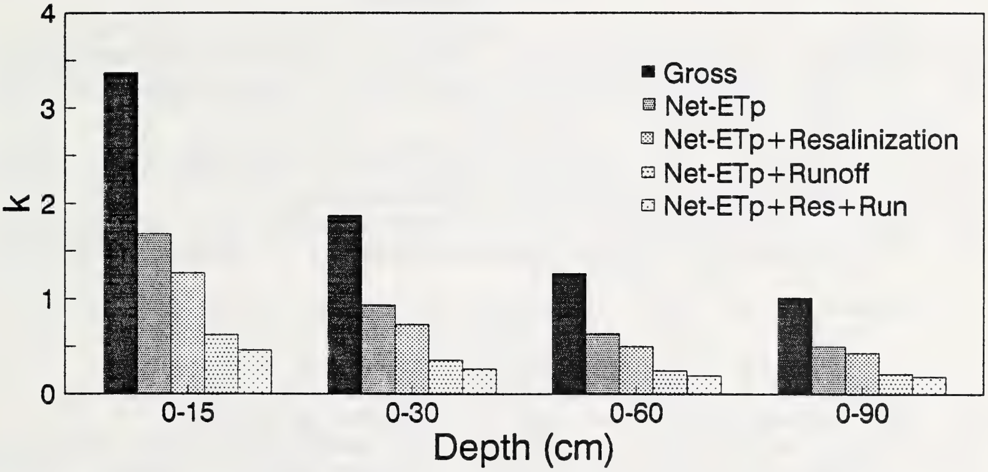

Fig. 3 Average values of the empirical constant, k, as a function of soil depth and method of determining depth of leaching water, dl, applied.

APPLICATION

As an example of an application of the above results, consider a farmer who has recently drained a saline soil which has salinity (electrical conductivity) levels of 20, 14, 8 and 6 dS/m for respective soil depths of 0-30, 30-60, 60-90 and 90-120 cm. He would like the average salinity to be reduced to about 8 dS/m but would also like to achieve a salinity in the surface 0-30 cm of soil of about 4 dS/m to ensure adequate germination. Runoff from the field is negligible. The farmer has noticed the land has been salinizing progressively over the past several years. How much leaching water (i.e. dl) is necessary?

The average starting concentration (Co) is 12 dS/m. The desired final concentration (C) is 8 dS/m. Rearranging the "Hoffman" equation yields:

dl= k x ds x (Co/C) or C= k x Co x (ds/dl)

Assuming we are correcting for ETp, the solution is

dl= 0.18 x 120 x (12/8) ≈ 32 cm.

The extent of leaching which would occur in the surface 30 cm of soil is

C= 0.29 x 20 x (30/32) ≈ 5.4 dS/m

Thus, the application of 32 cm of water (net) will not achieve the desired reduction in salinity from 20 to 4 dS/m in the surface 30 cm of soil. This would require about 44 cm of net water.

It is important to note that a lesser or greater degree of leaching may be obtained from within a season and between seasons depending upon runoff and resalinization. It is also important to stress the variability which was observed between sample locations, as indicated in Fig. 2. This may mean that average leaching may be achieved on a field basis but on a smaller scale greater or lesser degrees of leaching are very likely.

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ROOTING DEPTH AND SOIL WATER USE

OF TEN VARIETIES OF ALFALFA IN SOUTHERN ALBERTA

J.J. Miller and W. J. Read[1]

INTRODUCTION

The variety of alfalfa recommended for planting in a recharge area, for saline-seep control in Alberta, is based on research results from Montana (Brown and Cleary 1978). Research has been done in Alberta to compare yields of different alfalfa cultivars on a variety of soils (Wentz 1989), and on a drained saline seep (Beke and Graham 1989); however, data for rooting depth and soil water use of different alfalfa cultivars in Alberta are lacking. This data is needed to determine which alfalfa cultivar is most effective for rooting depth and consumption of soil water, and subsequent vegetative control of dryland salinization.

METHODS AND MATERIALS

The study site is located at the D. and G. Welsh farm (NE 23-2-15-W4) near Milk River. An alfalfa variety and fertilizer trial (Project 87-F003-1) conducted by Don Wentz has been in progress at this site since 1987. This study on rooting depth and soil water use utilizes these previously established alfalfa plots. Ten alfalfa cultivars were examined in this study (Table 1).

Table 1. Ten alfalfa cultivars used in this study.

Variety	Type	Root Type	Hardiness
Rambler	Dryland	Creeping	Excellent
Spredor II	Dryland	Strongly Creeping	Excellent
Pioneer 524	Standard	Tap	Good
Drylander	Dryland	Strongly Creeping	Excellent
Algonquin	Standard	Modified Tap	Medium
Trumpetor	Flemish	Modified Tap	Fair
Beaver	Standard	Deeply Rooted Modified Tap	Medium
Rangelander	Dryland	Strongly Creeping	Excellent
Pacer	Flemish	Modified Tap	Fair
Heinrichs	Dryland	Moderately Creeping	Excellent

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Investigations on rooting depth and water use were initiated in the spring of 1990. Ten alfalfa varieties replicated three times were chosen for this study. Three fallow plots were also created, adjacent to each of the three replicate plots. A total of thirty alfalfa plots and three fallow plots were instrumented in the spring of 1990. One access tube was installed in each of the thirty and fallow alfalfa plots to a depth of approximately 6.1 m (20 feet). Soil moisture was monitored every two weeks from spring to fall of 1990. A piezometer nest and observation well were also installed at the site to ascertain if vertical groundwater flow was upward (discharge) or downward (recharge).

Soil samples to a depth of 6.1 m were taken from each plot during auger- and coring-drilling operations during the growing season of 1990. Roots in soil and drift samples were then separated by sieving to determine presence of roots at a specified depth interval. Yield samples were obtained in 1990 by J. Payne and R. Ripley as part of the ongoing alfalfa variety and fertilizer trial study.

Rooting depth and soil water use for each alfalfa variety was determined from a graph of soil moisture versus depth for the alfalfa cultivar and the fallow plots (Fig. 1). Rooting depth was determined on the graph by the intersection of the alfalfa and fallow curves. Soil water use was calculated as the area between the two curves, from a depth of 25 cm to the depth of rooting. The results in this study are reported as mean yield, rooting depth and soil water use for the 3 reps. Mean values of soil moisture for the 3 fallow plots were used for all results.

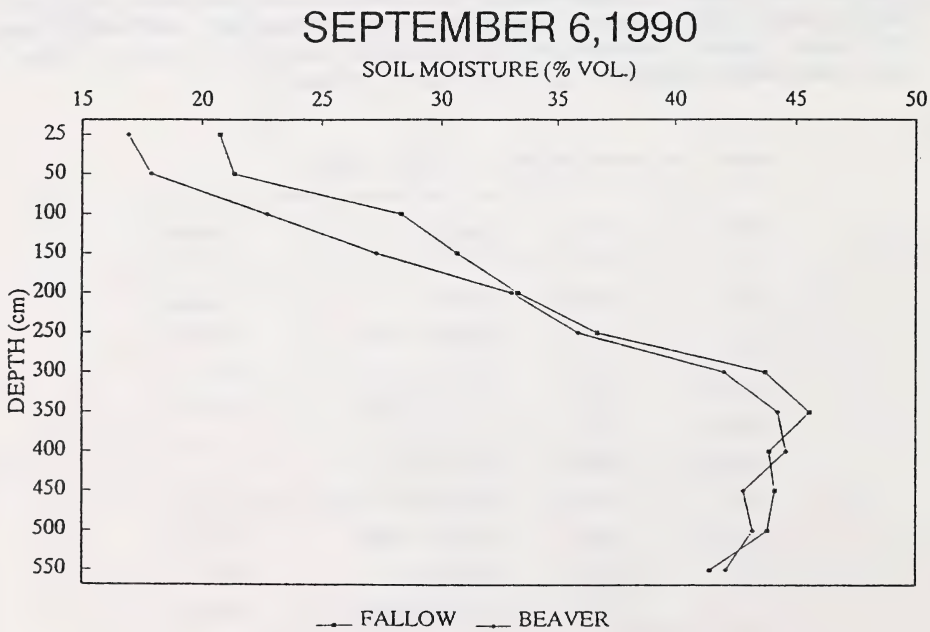

Figure 1. Example of graph used in determining rooting depth and soil water use for each alfalfa variety.

RESULTS AND DISCUSSION

Yield, rooting depth and soil water use of ten alfalfa varieties (means of three reps) during 1990 (Table 2) showed that Beaver had the highest yield (3413 kg ha^{-1}), followed by Rambler (3333 kg ha^{-1}) and Drylander (3016 kg ha^{-1}). Pacer exhibited the greatest rooting depth (2.17 m), followed by Beaver (2.00 m) and Drylander (1.71 m). Soil water use was greatest for Beaver (15.4 cm water), followed by Pacer (14.3 cm water) and Heinrichs (12.3 cm water). Beaver would be the cultivar to attain the best combination of yield, rooting depth and soil water use under the conditions found at this site.

Rooting depths determined by sieving of roots from soil and drift samples revealed that roots were detected to a maximum depth interval of 3.0 to 4.6 m for the varieties Algonquin, Beaver, Drylander, Rambler, and Heinrichs. Maximum rooting depth for the remaining varieties were all above this depth interval. Maximum rooting depth determined by this method (3.0-4.6 m) was greater than maximum rooting depth (2.17 m) determined by the soil moisture method. The differences probably reflect the different methods, and the errors associated with each method.

Comparison of rooting depth and soil water use values determined in this study to results from Montana (Brown et al. 1982) revealed much higher yields and rooting depths for the varieties Beaver, Rambler and Drylander in Montana. For example, the Montana researchers reported a mean yield (based on 5 year study) value of 4950 kg ha^{-1} and a rooting depth of 7.32 m for Beaver. These values are much higher than the yield (3413 kg ha^{-1}) and rooting depth (2.00 m) values reported in this study. Beke and Graham (1989) reported similar yield values for Beaver (4354 kg ha^{-1}) and Heinrichs (2630 kg ha^{-1}), but a much lower value for Drylander (1388 kg ha^{-1}), compared to our results. Their study was based on data from three growing seasons.

The differences in alfalfa yield and rooting depth from different studies are not surprising, considering the extreme variability of soils and other environmental conditions. The Montana study was performed in a recharge area with a deep water table and non-saline soils. These conditions were favourable for high water use and greater rooting depth. The study by Beke and Graham (1989) was performed on a drained saline seep with a shallow water table.

The environmental conditions found at this study site were extremely complex. Both saline and non-saline soils occurred within the alfalfa plots. Rep 1 was non-saline whereas Reps 3 and 5 were saline. The water table level at this site was greater than 3 m below the ground surface during 1990. Vertical groundwater flow, however, was complex. Vertical downward flow (recharge) from the water table to 6.10 m prevailed in the spring (June) and early summer (July) of 1990; whereas vertical upward flow (discharge) from a depth of 7.62 m prevailed in the fall (August and September) of 1990. Texture of soil and drift materials within the plots were dominantly clay loam in texture. In addition, severe drought stress during the summer of 1990 severly affected the growth of the alfalfa. Many plants exhibited severe drought stress, and a few plants died. The results from this study should thus be interpreted with caution because of the complex environmental conditions.

Table 2. Yield, rooting depth and soil water use of ten alfalfa varieties during 1990 (means of three reps).

Variety	Yield[a] kg ha^{-1}	Rooting Depth[b] meters	Soil Water Use[c] cm water
Beaver	3413	2.00	15.4
Pacer	2778	2.17	14.3
Pioneer	3175	N.A.[d]	N.A.
Rambler	3333	1.50	7.4
Rangelander	2540	1.55	7.5
Spredor II	2857	1.50	9.8
Trumpetor	2302	1.50	10.9
Algonquin	2778	1.62	12.0
Heinrichs	2619	1.64	12.3
Drylander	3016	1.71	8.6

a Yield based on 1990 harvest (dry matter yields reported on basis of moisture content of 50.3%).

b Rooting depth based on average of 4 dates (June 26, July 24, August 20 and September 6) during 1990.

c Soil water use based on totals of 4 dates (June 26, July 24, August 20 and September 6) during 1990.

d N.A. - Not applicable. Soil moisture for this variety was greater than fallow soil moisture.

SUMMARY

The results for the 1990 growing season indicate that the alfalfa cultivar for the best overall combination of yield, rooting depth and soil water use, would be Beaver. These preliminary results are valid for the environmental conditions found at this site. Subsequent work will involve resuming soil moisture monitoring in the spring of 1991, to obtain at least one more growing season of data. Renewal of this Farming For the Future, On-Farm Demo project has been accepted. A final report will be completed during the winter of 1991-92.

ACKNOWLEDGEMENTS

Field and laboratory work was performed by Valerie Sawchuk and Bill Read. Drilling assistance was provided by Allan Plesko, Curt Livergood, Eugene Kurinka and Jim Pittman. Jack Payne and Rob Ripley did the yield sampling. Gayna Welsh managed the funding for this project. Don Welsh harvested the alfalfa plots. Thanks are extended to Don and Gayna Welsh for their assistance in this project, and for the use of their land. Funding was provided by the Farming For the Future, On-Farm Demo program.

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HYDROLOGY AND SOIL SALINIZATION NEAR CROSSFIELD, ALBERTA

J.J. Miller and W.J. Read[1]

INTRODUCTION

The effectiveness of alfalfa in lowering water tables in the recharge and discharge (saline seep) areas has been examined by Brown et al. (1982). No studies, however, have been done to investigate the seasonal dynamics of hydrology and geochemistry of a saline seep and it's shallow groundwater system, before and after vegetative controls have been implemented. Previous studies have examined shallow groundwater in relation to dryland salinity in Alberta (Maclean and Pawluk 1975; Hendry and Buckland 1989; Hendry et al. 1989; Miller 1989; Stein 1989); however, none of these studies examined the effect of vegetative controls on the seasonal dynamics of soil salinization. This information is desirable because the effect of vegetative controls on hydrology and geochemistry associated with soil salinization can be ascertained. This is the objective of this study.

MATERIALS AND METHODS

The saline seep chosen for this investigation is located on the V. Machacek farm (SE26-28-28-W4), just east of the town of Crossfield. Four sites located in a transect perpendicular to the topographic gradient, from the bedrock ridge to the saline seeps at the lower slope positions, were selected for soil, hydrological and geochemical investigations (Fig. 1). Sites 1831 and 1832 are saline seeps located at lower slope positions, Site 1833 is located at the middle slope position, and Site 1834 is located at the upper slope position of the bedrock ridge.

Soil, drift and geological samples were obtained by auger drilling in April of 1990. Soil samples from each horizon to a depth of at least 1 m, and groundwater samples from each piezometer and well, were taken in the spring, summer and fall of 1990. Samples were transported to the laboratory for chemical analyses (pH, E.C., and soluble cations and anions).

Eleven piezometers and four observation wells were installed to depths ranging from 2.1 to 19.1 m. Two large-diameter wells were also installed, one on the bedrock ridge (Site 1834), the other in the saline seep (Site 1831). Stevens "A" type water level recorders were attached to each large well to continuously monitor the water table. A cut-throat flume and Stevens recorder were installed on a culvert along the road-ditch in the south-east corner of the quarter-section to monitor the inflow of surface water into the basin.

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LOCATION PLAN

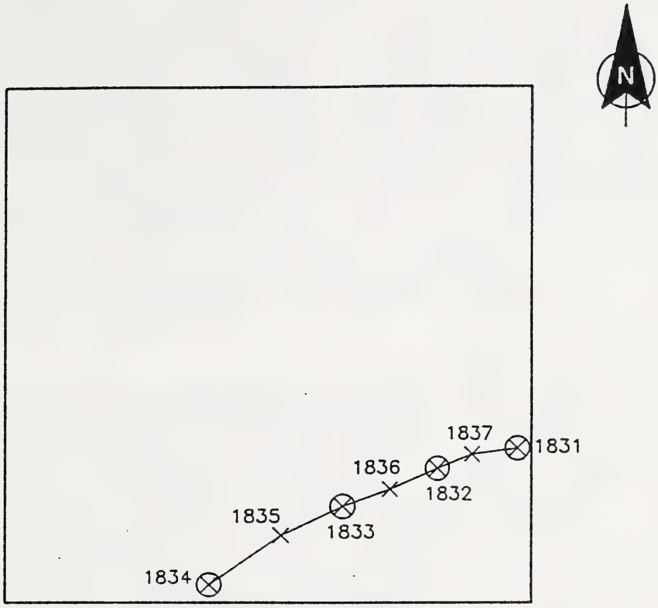

Figure 1. Study site (SE26-28-28-W4) used in this investigation.

RESULTS

The hydrogeology of the study area was dominated by till of clay-loam texture overlying sandstone-shale of the Paskapoo Formation. A major coarse-textured (sandy and gravelly) layer was found within the till, extending from below Site 1834 to Site 1833. Lateral groundwater flow was concentrated in this coarse-textured layer.

Surface-water discharge into this study basin occurred from March to June, 1990. Discharge was at a maximum in March (1400 m^3/month). The source of the surface-water discharge was snowmelt runoff derived primarily from accumulation of snow in the east-west road allowance bordering the southern boundary of this section. High rainfall in May and June may have also contributed to surface-water discharge into the basin during June.

The water table ranged from 0.25 m to 1.61 m at Site 1831 (saline seep) during 1990 ; at Site 1832 (saline seep) it ranged from 0.80 to 1.95 m; at Site 1833 (non-saline) it ranged from 2.00 to 3.00 m; and at Site 1834 (non-saline) it ranged from 1.77 to 2.58 m. The water table was closest to the soil surface at the two saline seeps during June.

Water flow in the soil at Site 1831 (seep) was upward from the water table to a depth of 30 cm, from April 23 to October 11, 1990. The

hydrograph for water flow at deeper depths (2-9 m) indicated both downward and upward vertical flow from and to the water table, respectively (Fig. 2). Discharge or upward flow to the water table occurred from 5, 7 or 9 m depths, during the period June 29 to September 27. Downward, groundwater flow occurred from 8 m to 19 m at Site 1832 (seep) during 1990 (Fig. 3). Similar hydraulic heads at the water table and 8 m indicated lateral groundwater flow beneath these depths. The slow recovery of the water level in the piezometer at 19 m suggested that equilibrium conditions had not yet been attained.

The tritium content of shallow groundwater (< 2 m) at Site 1831 was relatively high (4.7-8.5 T.U.), whereas deeper groundwater (5-8 m) had tritium contents < 1 T.U.. This suggested the presence of relatively recent shallow groundwater overlying older and deeper groundwater. The source of the recent and shallow groundwater was most likely meteoric water. The tritium contents of groundwaters from various depths (6-19 m) at Site 1832 were < 1 T.U., and indicated relatively old water of groundwater origin.

Soil and drift material were saline (E.C. > 4 dS m^{-1}) to a depth of 7.90 m at Site 1831; and to a depth of 2.10 m at Site 1832 (Table 1). Soil and drift were non-saline (E.C. < 4 dS m^{-1}) to a depth of 7.90 m at Sites 1833 and 1834. Electrical conductivity in the surface soil (0-15 cm) at Site 1831 was 8.1 dS m^{-1} in April, 12.6 dS m^{-1} in July, and 9.8 dS m^{-1} in October of 1990. The E.C. value in the surface soil (0-15 cm) at Site 1832 was 7.9 dS m^{-1} in April, 5.6 dS m^{-1} in July, and 4.4 dS m^{-1} in October of 1990. Electrical conductivity values of groundwater close to the water table at Site 1831 ranged from 10.3 to 14.3 dS m^{-1} in the spring, summer and fall of 1990. E.C. values of groundwater from the water table at Site 1832 ranged from 2.9 to 3.5 dS m^{-1} during these three seasons.

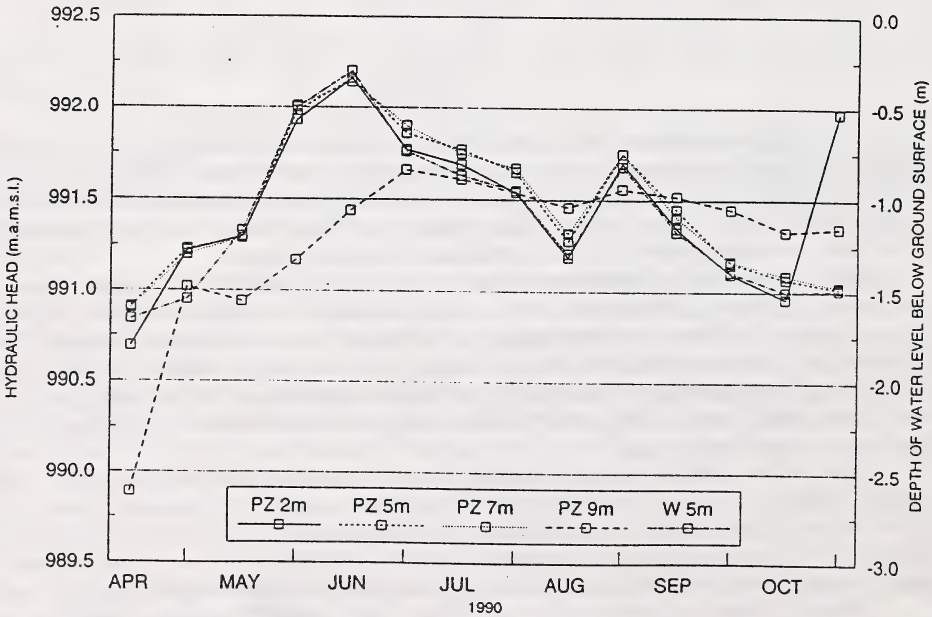

Figure 2. Hydrograph for Site 1831.

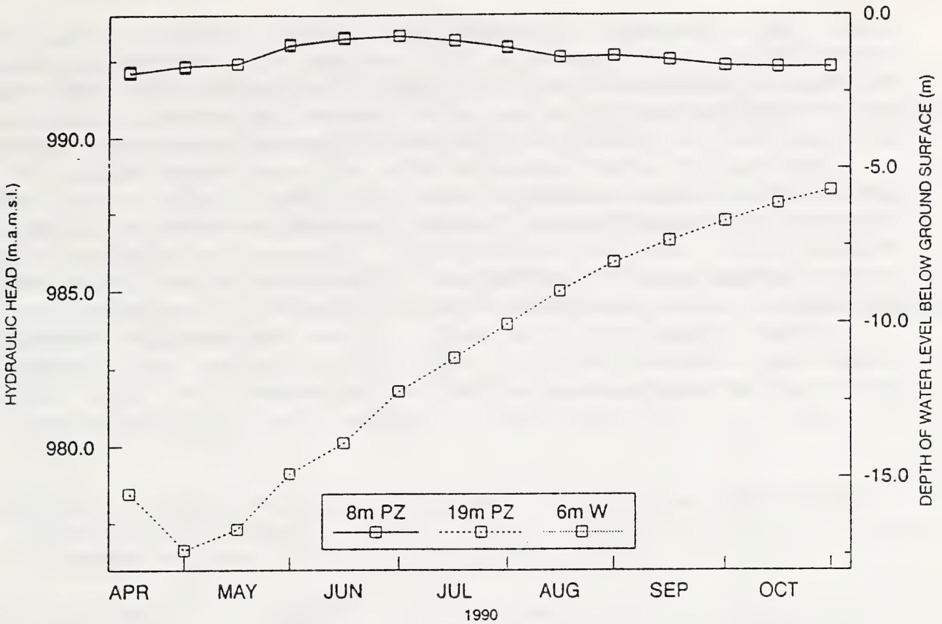

Figure 3. Hydrograph for Site 1832.

DISCUSSION AND SUMMARY

Soil salinization and a shallow water table at Site 1831 was caused by groundwater and surface water. Soil salinization at Site 1832 was caused only by groundwater. Depressions on the bedrock ridge were found to contain highly-leached soils; and historical air photos showed water in many of these depressions. The evidence from this study suggests the following is a likely scenario.

Depression-focussed recharge occurs through cultivated sloughs and soil water enters the shallow groundwater system. Shallow groundwater is transmitted laterally through the coarse-textured layer within the till. This permeable layer sub-crops at a shallow depth and just upslope of Site 1832. Lateral flow of groundwater through this sand and gravel layer, and the location of Site 1832 just downslope from the sub-cropping permeable layer, are conducive to the high water table (0.80-1.95 m) observed at Site 1832. Groundwater discharge and a shallow water table (0.25-1.61 m) at Site 1831 was also probably caused by depression-focussed recharge on the bedrock ridge, and lateral groundwater flow downslope through this permeable layer.

Surface water was also a cause of a high water table and soil salinization in the seep at the lowest landscape position (Site 1831). Evidence for this was surface-water discharge into the basin during March to June, 1990, evidence of surface water near Site 1831 during the study and on historical air-photos, and meteoric water with high tritium content in the shallow groundwater below this site. There was no evidence for a surface water contribution at Site 1832, which was located further upslope.

The shallow water table at Site 1831 was caused by both infiltration of surface water, and groundwater discharge from within the

till. Net discharge of water and soluble salts at this site was indicated by an increase in E.C. values with decreasing depth to a maximum in the surface soil. Soluble salts were derived from the highly saline groundwater (10.3-14.3 dS m^{-1}); and maximum salinization of the surface soil occurred in July, when evapotranspiration was highest.

The shallow water table at Site 1832 was caused mainly by lateral groundwater flow through the sand and gravel layer within the till. Some infiltration of meteoric water occurred as evidenced by leaching of soluble salts from the surface soil. Downward percolation of meteoric water, however, wasn't sufficient to penetrate to the water table. This was indicated by low tritium values of shallow groundwater.

Future plans for this study include implementing vegetative and mechanical controls in 1991, and then monitoring their effect on the hydrology and geochemistry of soil salinization.

TABLE 1. Electrical conductivity (E.C.) of soil and drift samples at four sites in April 1990

Depth (m)	E.C. (dS m^{-1})			
	Site 1831	Site 1832	Site 1833	Site 1834
0.00 - 0.30	14.8	7.8	1.0	1.5
0.30 - 0.60	13.2	10.9	1.7	0.9
0.60 - 0.90	11.6	8.7	3.3	0.9
0.90 - 1.20	11.4	6.7	2.8	0.7
1.20 - 1.50	11.4	5.9	1.5	0.5
1.50 - 1.80	10.9	5.1	1.4	0.6
1.80 - 2.10	10.5	4.3	1.4	0.6
2.10 - 3.70	8.7	3.9	1.1	0.4
3.70 - 4.60	6.6	3.9	1.0	0.5
4.60 - 4.90	5.6	3.3	1.0	0.7
4.90 - 6.10	5.1	3.2	1.0	1.0
6.10 - 6.40	5.2	3.2	1.2	1.1
6.40 - 6.70	4.5	3.2	1.2	1.1
6.70 - 7.60	4.5	3.2	1.2	1.0
7.60 - 7.90	4.1	3.3	1.1	1.0

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CHEMICAL QUALITY OF PLANTS, SOILS AND SHALLOW GROUNDWATERS OF SALINE SEEPS IN SOUTHERN ALBERTA

J.J. Miller and W.J. Read[1]

INTRODUCTION

Dryland salinity causes degradation of our soils. Dryland salinity may also cause deterioration in the quality of our shallow groundwater resources. A regional water-quality inventory of the Montana Plains found that significant water-quality deterioration had occurred in the glaciated portion of Montana where dryland farming had been practiced for many years (Miller et al. 1978). Significant concentrations of trace elements, particularily selenium and boron, were found in many of the groundwater samples.

The deterioration of shallow groundwater resources associated with saline-seep development is also a major concern in western Canada (Prairie Farm Rehabilitation Administration 1983). Shallow groundwater in Alberta may be used for drinking water, livestock water, or for irrigation. High concentrations of sodium in irrigation water will cause undesirable effects on soil properties and plant growth. High nitrate concentrations in saline-seep waters pose a potential health hazard to people and livestock. High concentrations of sulfate in saline-seep water that is used for livestock-water can contribute to bovine polioencephalomalacia (Beke and Hironaka, 1990, personal communication).

Trace elements in soils and their role in the soil-plant-crop system has been examined by Kubota et al. (1987) and Tiller (1989). Trace element contents of soils in Canada have been reported by various authors (Mills and Zwarich 1975; Dudas and Pawluk 1980; McKeague and Wolynetz 1980); however, few studies have examined trace element contents of saline soils. A study is in progress on the trace element content of salt-crusts within saline seeps of Alberta (Kohut, C. and M. Dudas, 1991, pers. comm.).

Considerable analyses have been done on the nutritive and chemical quality of forages grown in Alberta (Alberta Agriculture 1987); but only a few studies have reported on the feed and chemical quality of plants growing on saline seeps (Vander Pluym 1977; Wentz 1989).

The Dryland Salinity Investigation Service (DSIS) of Alberta Agriculture recommends seeding salt-tolerant forages in the saline seep as a possible vegetative control measure. If toxic levels of inorganic chemicals are present in shallow groundwaters and soils of saline seeps, then these toxic elements may accumulate in the forages, and subsequently in livestock and humans. This may have important implications with regards to animal nutrition.

The objective of this study is to sample plants, surface soils and shallow groundwaters within saline seeps in southern Alberta, to ascertain if toxic levels of chemicals are present. The focus will be on trace elements as these chemicals are most important with regards to animal nutrition.

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MATERIALS AND METHODS

Plant, soil and groundwater samples were obtained from 15 different DSIS investigation sites (saline seeps) in the County of Warner, and at 15 sites (seeps) in the County of Forty-Mile. Samples were transported back to the laboratory the same day and prepared for analyses. Plant samples were oven-dried at 65 degrees C. for 24 hours, placed in plastic bags, and stored in a deep-freeze until analyzed. Soil samples were air-dried and stored. Saturation-paste extracts were later obtained, and solution- extracts stored at 4 degrees C. until analyzed. Groundwater samples were filtered through a 0.45 micrometer filter in the lab, and acidified. Electrical conductivity, pH, nitrate, and bicarbonate and carbonate contents were determined on water samples within 48 hours. Water samples were stored at 4 degrees C. for later analyses of trace elements.

Trace elements in plant, soil and groundwater samples were determined by ICP (Inductively Coupled Plasma) in the Soil and Animal Nutrition Laboratory of the Plant Industry Division of Alberta Agriculture, Edmonton. Trace elements in soils and water samples were also determined by atomic absorption techniques in the laboratory of the Land Evaluation and Reclamation Branch of Alberta Agriculture in Lethbridge. The following chemical constituents will be determined in plant, soil and water samples: Ca, Mg, Na, K, SO_4, Cl, Al, Cd, Cr, Cu, Hg, Fe, Mn, Mo, Zn, Pb, Co, As, Se, P, S, B, and I.

PROGRESS REPORT

The following elements or compounds in shallow groundwaters of the 30 saline seeps were found to exceed maximum recommended limits for livestock water quality (Environment Canada 1987). These elements or compounds, in decreasing order of abundance, were nitrate > sulfate > lead > fluorine > cadmium > mercury (Table 1).

The following elements in plants within the 30 saline seeps were found to exceed maximum recommended limits for livestock feed and water quality (Alberta Agriculture 1987; Environment Canada 1987). These elements, in decreasing order of abundance (Table 1), were copper (sheep and cattle) = molybdenum = aluminum = boron = cadmium = lead > copper (swine and poultry) > nitrate > cobalt.

The following elements in shallow groundwaters of the 30 saline seeps were found to exceed maximum recommended limits for irrigation water quality (Environment Canada 1987). These elements, in decreasing order of abundance, were molybdenum > lead > zinc = cadmium = chloride > selenium (Table 1).

Sampling will resume in the Counties of Lethbridge and Vulcan in the spring of 1991.

ACKNOWLEDGEMENTS

We thank Dan Heaney and staff of the Soils and Animal Nutrition Laboratory (Soils Branch), Edmonton; and Lab Services (Land Evaluation and Reclamation Branch), Lethbridge for their assistance.

Table 1. Chemical quality of groundwater and plant samples from Counties of Warner and Forty-Mile.

Sample	Chemical	% of Sites > Max. Limit	Max. Limit ppm	Type of Guidelines[d]
water	nitrate	100	100	livestock
water	sulfate	60	1000	livestock
water	lead	40	0.1	livestock
water	fluorine	20	2.0	livestock
water	cadmium	17	0.02	livestock
water	mercury	7	0.003	livestock
plant	copper	100	0.5[a],1.0[b]	feed
plant	molybdenum	100	0.5	feed
plant	boron	100	5.0	feed
plant	cadmium	100	0.02	feed
plant	lead	100	0.1	feed
plant	aluminum	100	5.0	feed
plant	copper	60	5.0[c]	feed
plant	nitrate	53	100	feed
plant	cobalt	7	1.0	feed
water	molybdenum	60	0.05	irrigation
water	lead	40	2.0	irrigation
water	cadmium	37	0.01	irrigation
water	zinc	37	5.0	irrigation
water	chloride	37	700	irrigation
water	selenium	3	0.02	irrigation

[a] sheep

[b] cattle

[c] swine and poultry

[d] livestock and irrigation water quality guidelines are from Alberta Environment (1987). Feed quality guidelines are from Alberta Agriculture (1987). Livestock water quality were used when feed quality criteria were absent.

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SALT REMOVAL WITH FALL IRRIGATION IN A SALINE, DRAINED SOIL UNDER PIVOT IRRIGATION

D. Millette,[1] C. Madramootoo[2] and G. D. Buckland[3]

INTRODUCTION

The use of subsurface drainage to reclaim saline lands under irrigation has been shown to be successful in several studies (eg: Buckland et al. 1986; Bennett et al. 1982). These studies have applied irrigation water by either flood or side-roll sprinkler irrigation. These irrigation methods apply high amounts of water (about 75 mm or more) in an individual irrigation event and this contributes to leaching. More land under pivot irrigation is becoming subsurface drained and the generally low amounts of water applied in a single irrigation event (20-40 mm) may restrict leaching and reclamation. Pohjakas (1984) reports that pivot irrigation, on average, meets only about 65% of the consumptive use of crops.

Application of water during the fall, when crop consumptive use is low, may allow more of the applied water to contribute to leaching. McMullin et al. (1983) found significant reductions in salinity in an undrained soil which was fall irrigated, but seasonal increases in salinity occurred because of the persistence of shallow water table. The present study was conducted to determine the effect of fall irrigation on salinity levels in a pivot irrigated, subsurface-drained field.

MATERIALS AND METHODS

The site selected (NE9-9-11-W4) was subsurface drained as part of seepage control along the SMRID main canal in 1986. The drains were placed at a 1.4-m depth and 15-m spacing. Soil salinization had resulted from a combination of groundwater discharge from an underlying coal seam (7-m deep) and seepage from the irrigation canal. Soils were saline and carbonaceous phases of Orthic Brown and Gleyed Brown Chernozems and Orthic Gleysols. The soils had developed in a thin lacustrine or fluvial veneer overlying glacial till.

Two testplots were established at the site. Plot one received conventional water applications by a center pivot (designated CP); plot two received the same center pivot irrigation plus additional irrigation

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in the fall (designated CP+FI) using a solid-set sprinkler system designed to apply an amount of water equivalent to that applied during a pivot irrigation event (about 35 mm). Water applications for both plots are given in Table 1.

Table 1. Net water applications

Time Period	Treatment	
	CP	CP+FI
87-08-01 to 87-10-10	152	290
87-10-11 to 88-04-10	41	41
88-04-11 to 88-07-31	421	421
88-08-01 to 88-10-10	115	321

CP = conventional pivot irrigation
CP+FI = conventional pivot irrigation plus fall irrigation

Additional testing on the two plots included determination of hydraulic conductivity using the auger-hole method (van Beers 1983) and monitoring of water-table wells placed at the midspacing between the drains. Soil samples were taken at six locations in each plot at depths of 0-15, 15-30, 30-60 and 60-90 cm. Soil samples were first collected on September 02, 1987, prior to the fall irrigations. Thereafter soil samplings were conducted on October 06, 1987 (after fall irrigation), April 28, 1988 (spring), August 29, 1988 (following conventional pivot irrigation) and finally on October 19, 1988 (following the second fall irrigation cycle). All soil samples were analysed to determine salinity and sodicity of saturation paste extracts using standard methods (Rhoades 1982).

RESULTS AND DISCUSSION

Average hydraulic conductivities (K) for the soil zone above and below the drains, respectively, were 0.049 and 0.043 m/d in the CP plot. For the CP+FI plot respective K's were 0.040 and 0.028 m/d. These K's are low but are within the range normally encountered in till materials. The similarity in K between the two plots suggests the water-table response to irrigation and drainage would be similar. This was found to be the case and additional information can be found in Millette (1989).

Salinity and sodicity levels for the two irrigation treatments, at different times of the year, are given in Fig. 1. Average profile salinity in the 0 to 90-cm depth was similar for both plots: 13.5 dS/m for CP and 11.4 dS/m for CP+FI. Following the first fall irrigation, relative salinity (EC/ECo) was reduced slightly in the CP and CP+FI

plots. Salinity reductions occurred to a greater depth in the CP+FI plot. These changes in salinity, when compared to the initial sampling (ECo), were not statistically significant. Salinity ratios in April 1988 were higher than those measured the previous fall in both treatments indicating overwinter salinization had occurred. This overwinter salinization was significant in the upper 0.6 m in both treatments. Salinization continued through the summer months (Fig. 1) and was significantly higher in the CP+FI plot in August, 1988 compared to April, 1988, but not in the CP plot.

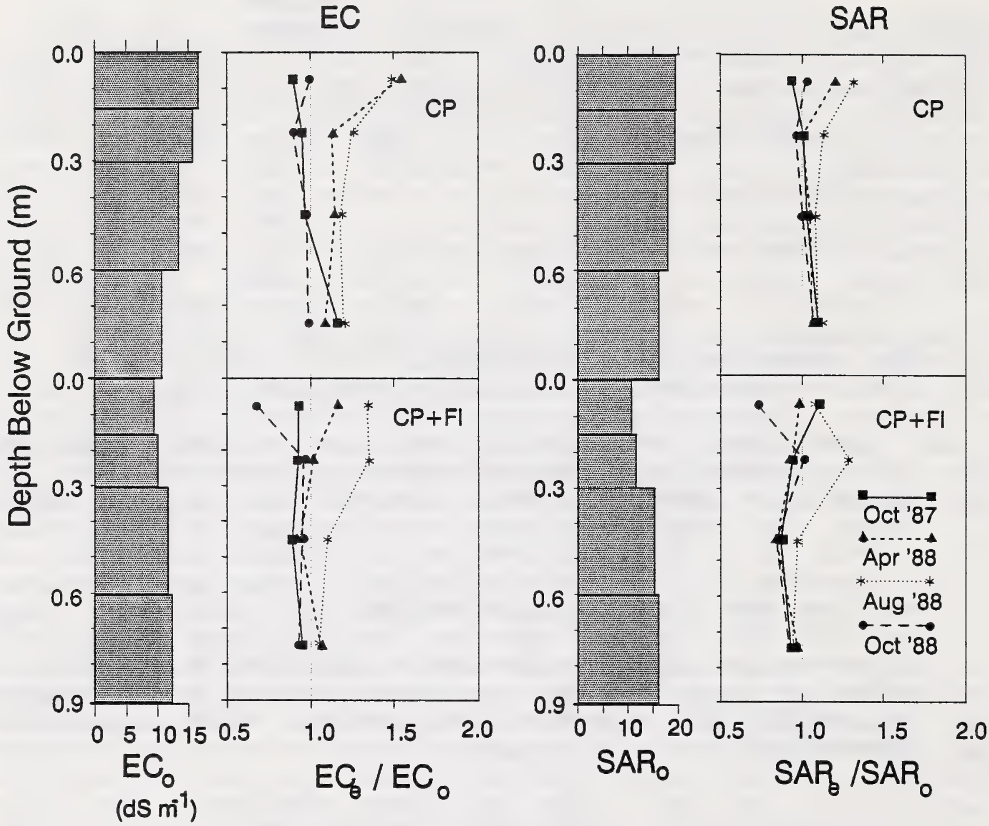

Figure 1. Initial salinity (EC_o) and sodicity (SAR_o) and subsequent relative changes (EC/EC_o, SAR/SAR_o) under conventional center-pivot irrigation (CP) and conventional center-pivot irrigation plus fall irrigation (CP+FI).

After completion of the second season of fall irrigation (October 1988) salinity was lower in both the CP and CP+FI plots. Salinity levels were lower in the CP+FI plot than in the CP plot, most notably in the 0 to 15-cm depth. Salinity in the 0 to 15-cm depth was reduced by 32% in the CP+FI plot but remained unchanged in the CP plot. Average profile salinity in the 0 to 90-cm depth was 13.1 dS/m for the CP plot and 10.2 dS/m for the CP+FI. Thus, salinity in the CP plot was 97% of the original value and for the CP+FI plot salinity was 90% of the original value.

Changes in SAR resulting from the two irrigation treatments parallel those observed with salinity (Fig. 1). The only minor difference between EC and SAR is that the initial SAR tended to be slightly higher than salinity. The initial profile-average SAR (0-90 cm) were 17.9 and 14.2 for the CP and CP+FI plots, respectively, while final values on October 1988 were 20.3 and 12.5. Thus, the final profile-averaged (0 to 90 cm) SAR's in the CP and CP+FI plots were 102 and 88% of the original values, respectively. For the CP+FI plot the reduction in SAR occurred primarily in the upper 15 cm of soil.

SUMMARY AND CONCLUSIONS

The use of fall irrigation appears to have had some effect on reducing salinity and sodicity over and above that provided by conventional pivot irrigation alone. By applying an additional 344 mm of water over two fall seasons, the average salinity and sodicity of 0.9 m of soil were both reduced to about 90% of original values compared to essentially no change in conventionally irrigated plots. Reductions in the EC and SAR of the surface 15 cm of soil were greater and were 32 and 27%, respectively.

Results suggest that short term salinity control in the seedbed may be possible using fall irrigation. Salt infusion from shallow, saline groundwater caused minor overwinter salinization. This overwinter salinization has been observed by several authors (eg: McMullin et al. 1983; Buckland and Hendry 1988) and is largely beyond the control of the farmer. It undoubtedly will increase the time required to achieve reclamation. More alarming was the observed increase in salinity from spring to late summer. Water application during this period is under the control of the farmer and higher water applications should be encouraged to ensure gains made in leaching salts in previous years are not lost.

A copy of this study can de obtained by contacting Alberta Agriculture in Lethbridge.

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RECLAMATION OF A SALINE SOIL ADJACENT TO A POLYLINED CANAL IN THE EASTERN IRRIGATION DISTRICT (EID)

K. M. Riddell[1]

INTRODUCTION

The Irrigation and Rehabilitation and Expansion (IREP) Reclamation Effectiveness Study represents a continuation of work evaluating the effectiveness of various seepage control measures on saline soil reclamation. The study responds to a need to document reductions in seepage-affected land associated with the existing IREP program (Coopers and Lybrand 1987).

The current study builds on the findings of previous research (Millette et al. 1989; Bennett 1990) and has the following objectives:

1. To provide a landscape model for representative saline/ waterlogged areas prior to canal rehabilitation. Soil profile information, near surface stratigraphy (0-4.5 m), water-table conditions, surface drainage, irrigation practices, and available hydrogeological information will be incorporated.
2. To monitor fluctuation of the water table and changes in the spatial and vertical distribution of salts within affected land units following canal rehabilitation.

Because of the large number of canals under investigation in this program, only a representative sample is reported here.

METHODS

The project area is located in the NE 13-16-16-W4 and the SE 24-16-16-W4 along an irrigation canal in the Eastern Irrigation District (Figure 1). The canal being rehabilitated in this study was built in the

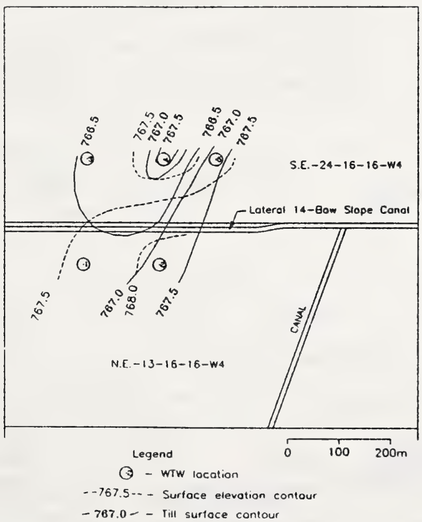

Figure 1. Site location plan, till surface and ground surface contours for E.I.D. ICW reclamation site.

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early 1900's and was constructed in a fill section across coarse-textured soils. Previous attempts to control seepage by excavating surface ditches adjacent to the canal had proved unsuccessful. Canal rehabilitation was conducted in the winter of 1990 and involved the installation of a buried, plastic membrane liner to control seepage.

The site was selected and instrumented according to methods for the IREP Reclamation Effectiveness Study outlined by Riddell and Bennett (1989). Water-table wells were installed on May 5, 1989 and have been monitored bi-weekly during the irrigation season and monthly from November to April since installation. EM-38 surveys were done in the fall of 1989, and spring and fall of 1990, using the automated cart method (McKenzie et al. 1988).

Soils in the study area consist of a mixture of Calcareous and Rego Brown Chernozemic developed on a discontinuous veneer of sandy loam fluvial material overlying clay loam till. The till is moderately saline-sodic with electrical conductivities (EC) ranging from 2 to 7 dS/m and sodium adsorption ratios (SAR) ranging from 6 to 15. Solonetzic soils are found in isolated patches where there is no fluvial material covering the till.

RESULTS AND DISCUSSION

The level in water-table well (WTW) #3 demonstrates a significant response to canal turn on prior to canal rehabilitation in the spring of 1989 (Figure 2). Water table levels in WTW #2 show only a very small response to canal turn on (Figure 2). WTW #1 also shows a dramatic response to canal turn on in the spring of 1989 (Figure 3). Reasons for

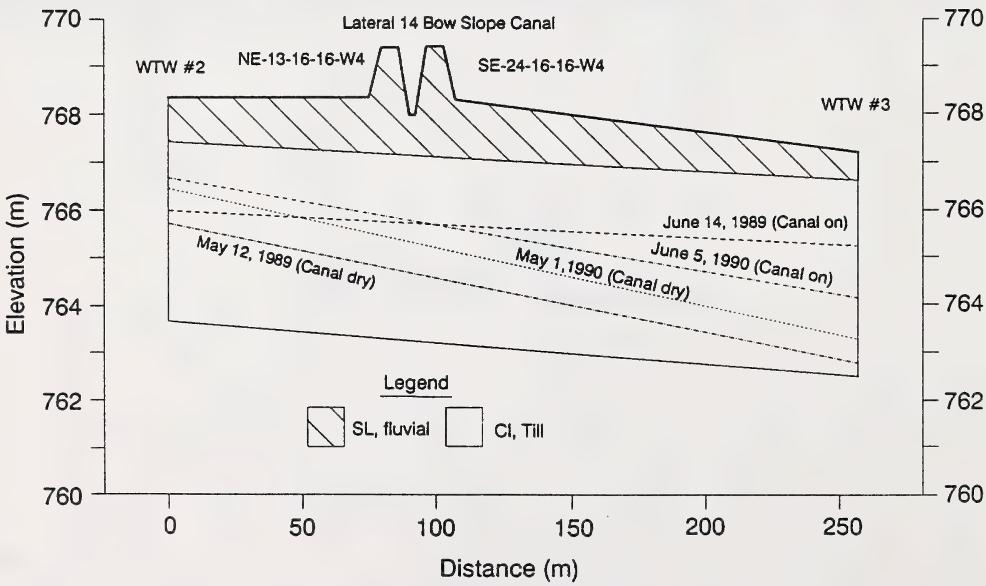
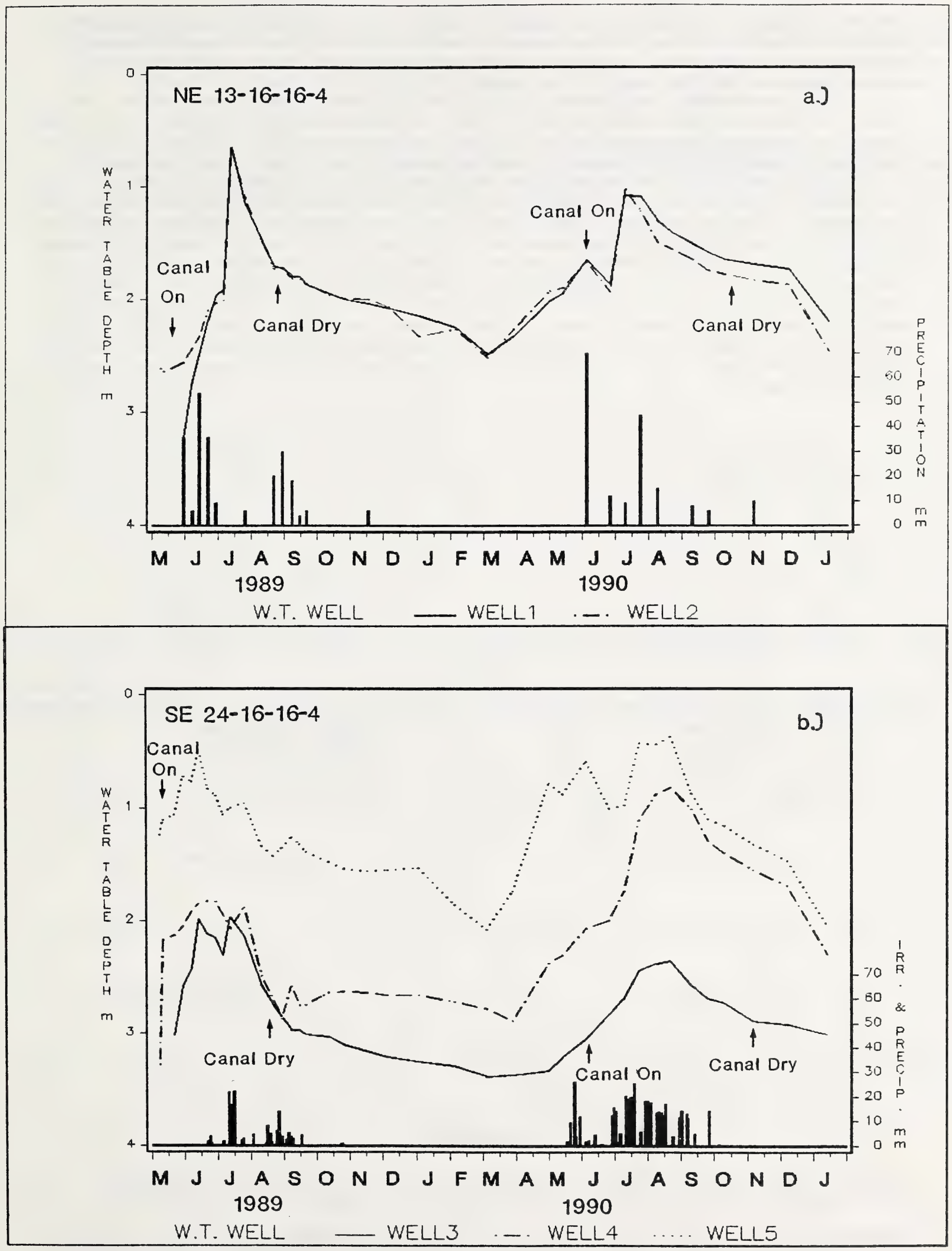


Figure 2. Cross section and selected water table elevations for WTW's 2 and 3 at EID ICW reclamation site during the spring of 1989 (prior to canal rehabilitation) and spring of 1990 (after canal rehabilitation).



ure 3. Water table hydrographs for WTW's 1 through 5 at E.I.D. ICW Reclamation site.

the more dramatic response in water-table levels at WTW #1 and 3 include the direction of slope of the ground surface and till surface (Figure 1). Seepage from the canal is probably directed along the till surface which drains towards WTW #1 and #3 (Figure 1).

In the spring of 1990, after canal rehabilitation, water-table levels in WTW #3 demonstrate much smaller fluctuations (Figure 2). The rise in water-table elevation at WTW #3 between May 1 and June 5, 1990 is attributed to precipitation (70 mm) falling during the month of May.

EM-38 salinity maps for the fall of 1989 and 1990 (Figure 4a, b) indicate no change in the distribution or levels of salinity between the two years. This suggests there has been no immediate effect of canal rehabilitation on soil reclamation. Interpretation of salinity maps produced using EM-38 numbers and empirical equations must consider that the accuracy of this technique in detecting salinity in specified categories (0-2.5, 2.5-5.0, 5.0-10.0, and > 10 dS/m), relative to soil sampling/laboratory techniques, is only 65% (Rhoades et al. 1990). Soil salinity, determined by soil sampling/laboratory techniques taken in the fall of 1989 and fall of 1991, will be compared in upcoming applied research reports.

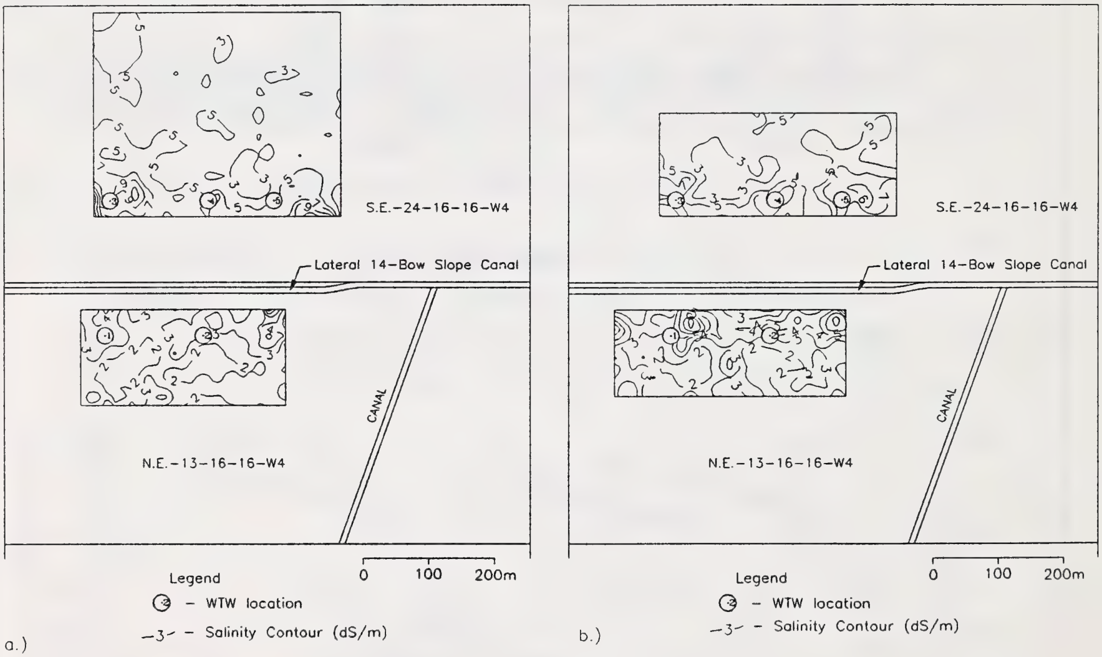


Figure 4. EM-38 salinity contours for E.I.D. ICW reclamation site: a.) Fall, 1989 prior to canal rehabilitation; b.) Fall, 1990 after canal rehabilitation.

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SALINITY MONITORING AT CUT AND FILL SITES

R. C. McKenzie and N. F. Clark

In 1984, an attempt to locate sites to evaluate methods of reclaiming cut portions of land levelled fields was unsuccessful because potential cut sites were usually saline. Therefore this project was initiated to monitor salinity changes on cut sites to determine how irrigation affected newly exposed saline areas. Two sites were first sampled in 1984 and since 1985 have been sampled biennially.

Methods

Nine sampling points were located by triangulation on each of two sites. Three of the original sample points in the second site were disturbed by earth moving equipment and were subsequently dropped from the experiment. The sites were sampled until the fall of 1989. They were sampled three times in 1984, twice in 1985 and once in each of 1987 and 1989. In each of the four years there was a sample taken in the fall. Extra samplings were taken in May 1984, August 1984, and May 1985. Although all the data is displayed in this report, comparisons are made between the fall samples only in order to limit seasonal variability.

Samples were collected in 0.30 m increments to a depth of 1.50 m for all sites except for August 1984 which was samp to a depth of 1.20 m. Soil salinity levels were determined by the 1:2 soil-to-water sus nsion method. The results were then corrected to an equivalent saturated paste extract electrical conductivity value.

The first site (NE 9 19 14 W4), has a medium textured soil. The site was irrigated by two side roll sprinkler systems, one covering sites H1-H4 and the other sites H5-H9. Sites H1-H7 were cut sites while H8-H9 were fill sites. The soil at the second site (NE 6 17 12 W4) was fine-medium textured and was surface irrigated. Salinity records for site 1 are presented in Fig. 1 and Table 1 and site 2 in Fig. 2 and Table 1.

Results and Discussion

The amount of water applied to the grass hay crop on Site 1 was estimated by the farmer to be approximately 300 mm per year in three irrigations for the first 4 years. In the final year, five irrigations were applied providing approximately 400 mm of irrigation water.

An annual cereal crop at site 2 received two flood irrigations. The amount of water applied was not determined. Records on timing and frequency of irrigation were not kept.

Examination of the data for site 1 shows that there were fluctuations in the salinty values. There wasn't a consistant upward or downward movement of salts either within the root zone or over time at any one sampling point. The average data for the fall samplings showed a decrease in electrical conductivity in the 0.0 m to 0.3 m zone but overall there was an increase in EC at the four deeper depths.

On site 2 there were only three surface samples that showed any reduction in EC values between fall 1984 and fall 1989. All other measurements were higher over the same time period and on the average there was a marked increase in salinity at all depths within the root zone.

Annual precipitation in millimetres at the ASCHRC at Brooks was 360, 354, 393, 277, 251, and 246 for 1984 to 1989, respectively. The ASCHRC meteorological station is 5 km southeast of Site 1 and 20 km northwest of Site 2. This data indicates that 1984 to 1986 had normal to above average precipitation and 1987 to 1989 had below normal precipitation. This may have been a contributing factor to the increase in salinity at site 2. At site 1 in 1989, the farmer increased the amount of irrigation which reduced upward movement of salts.

Conclusion

In site 1 salinity has not appreciably changed. In site 2 the salinity has increased in both surface and subsurface layers since the project was started in 1984. Changes in salinity concentration of surface soils after land levelling appear to be determined by the irrigation management. Movement of the salts in the root zone is affected by water applied and as a result during extended dry periods the salts will return to the surface. A shift from flood to sprinkler irrigation should allow for reduction in salinity in surface layers on site 2.

This series of biennial measurements of salinity will be discontinued at the end of 1989. Any further observations on these sites should include the establishment of water table wells and monitoring seasonal movement of the water tables and measurement of rainfall and irrigation inputs.

Fig. 1. Salinity profiles for seven sampling dates for site 1.

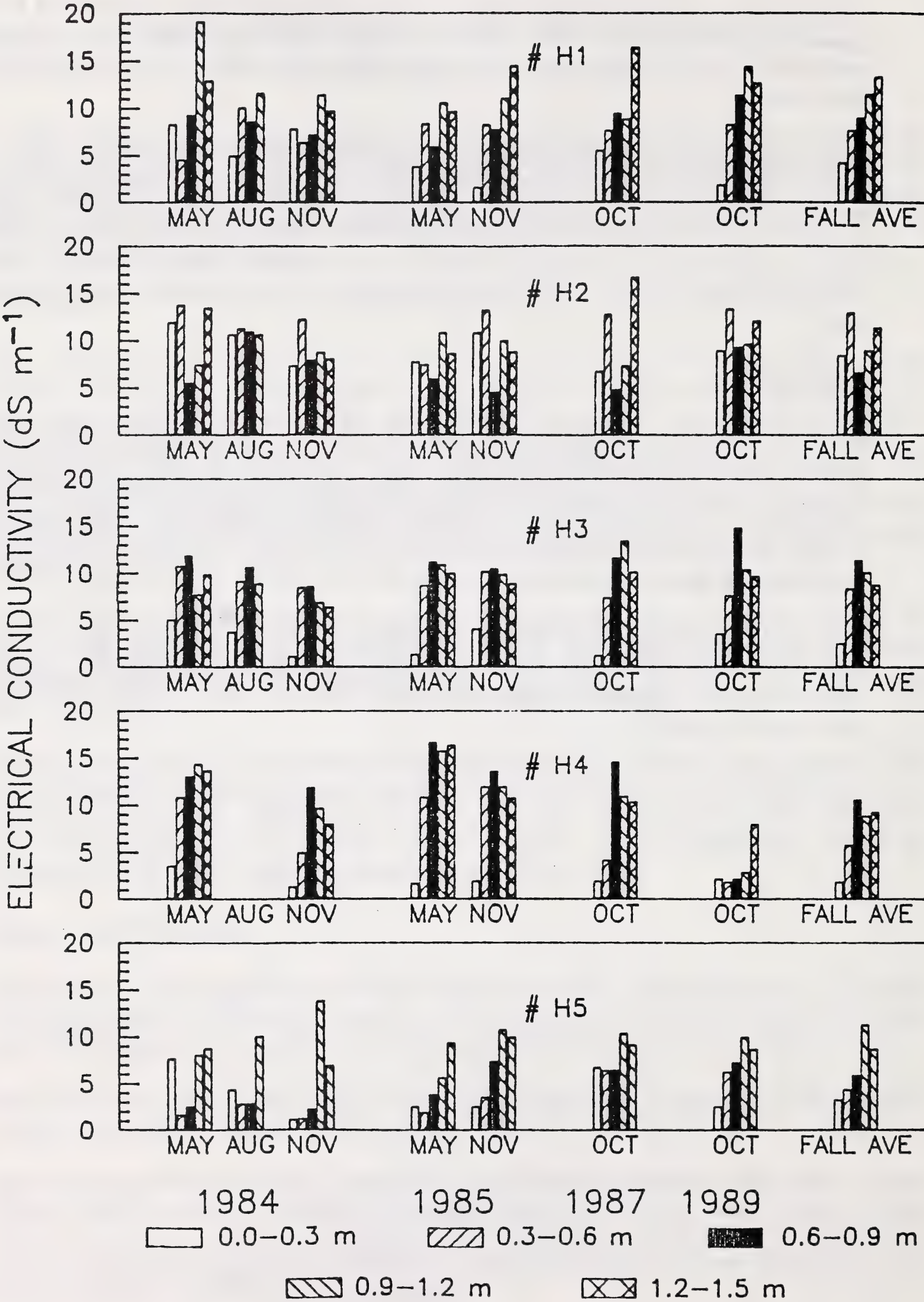
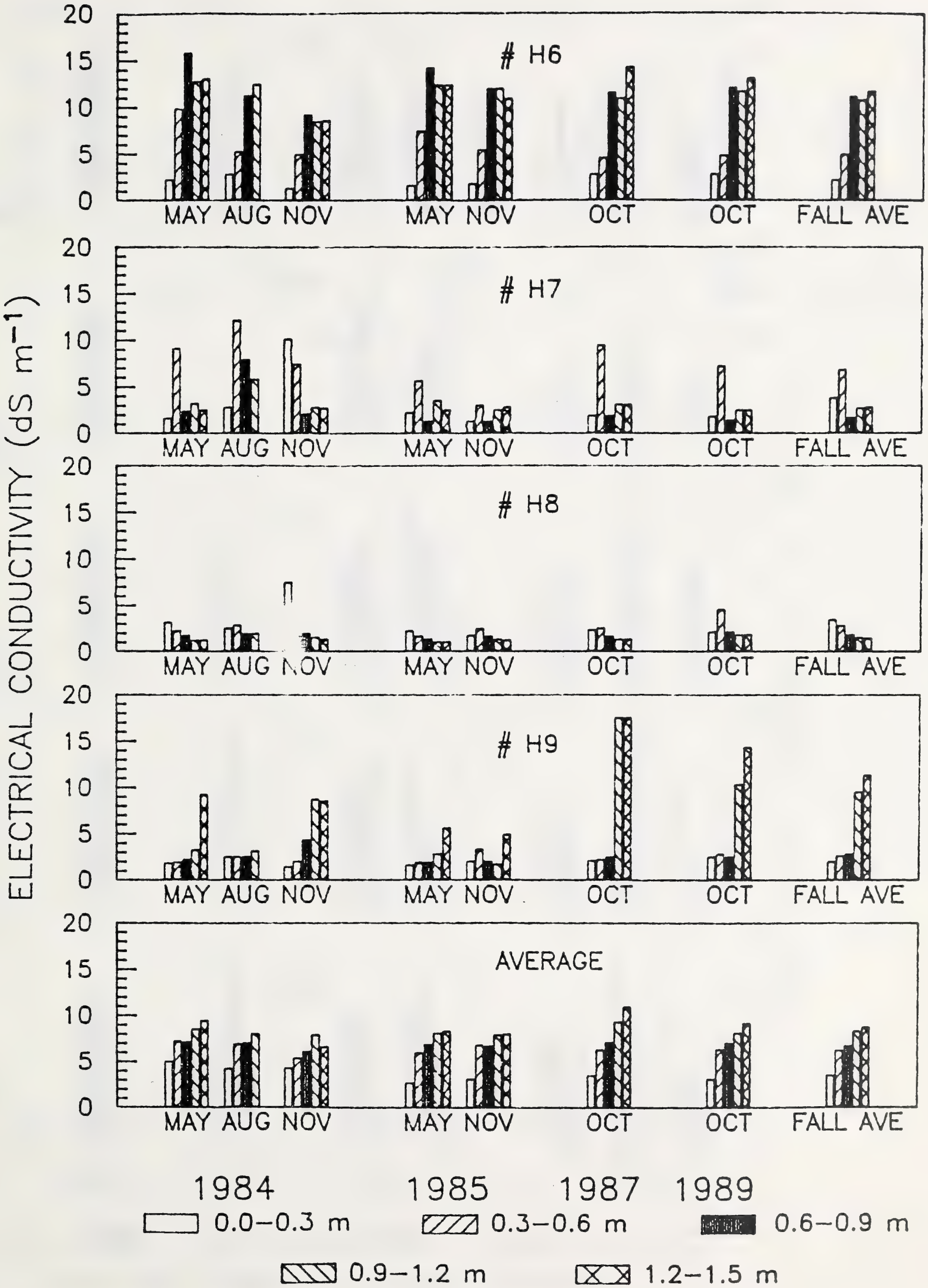


Fig. 1. Cont'd



ELECTRICAL CONDUCTIVITY (dS m-1)
H6
H7
H8
H9
AVERAGE
20
15
10
5
0
MAY AUG NOV MAY NOV OCT OCT FALL AVE
1984 1985 1987 1989
0.0–0.3 m
0.3–0.6 m
0.6–0.9 m
0.9–1.2 m
1.2–1.5 m

Fig. 2. Salinity profiles for seven sampling dates for site 2.

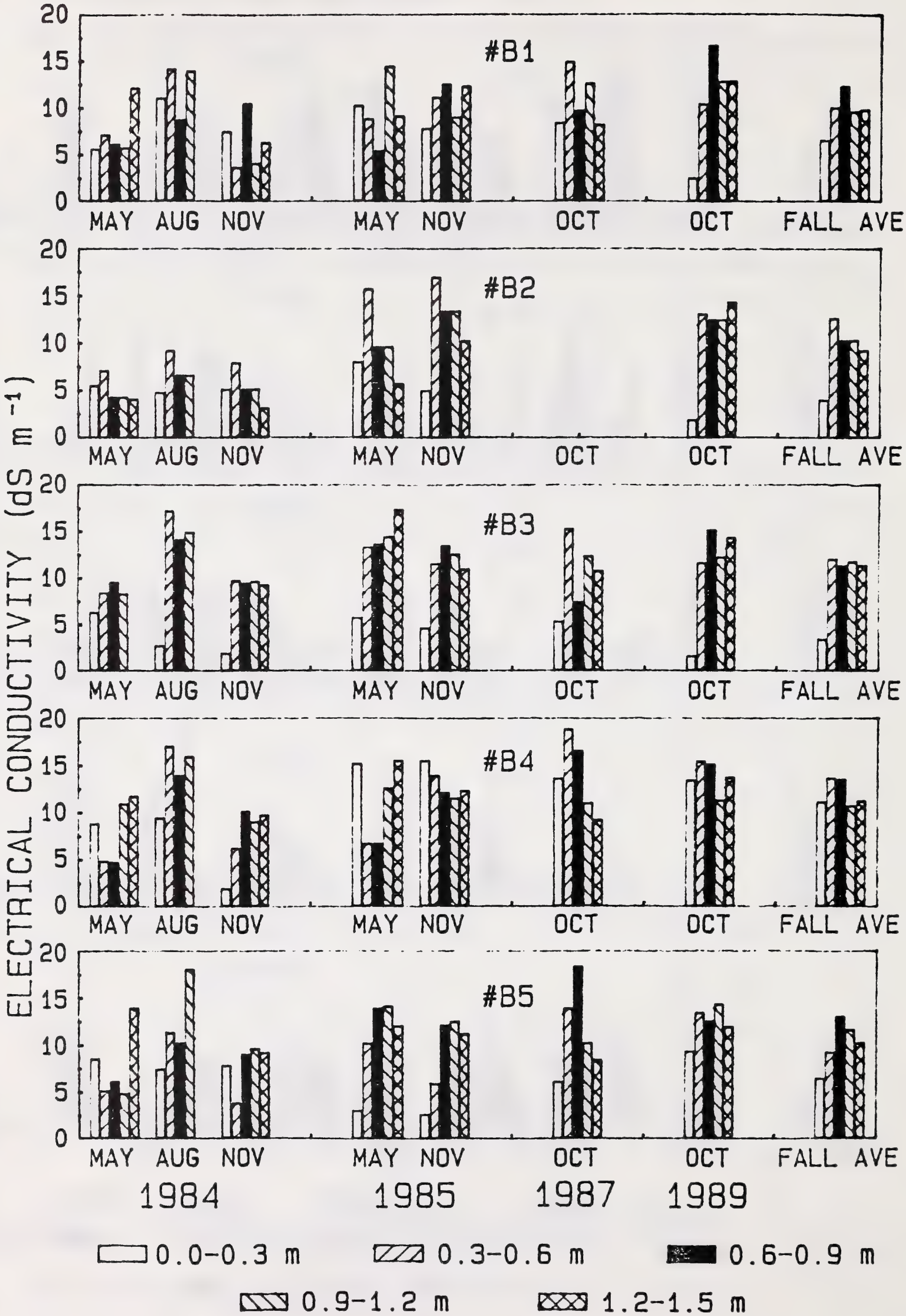
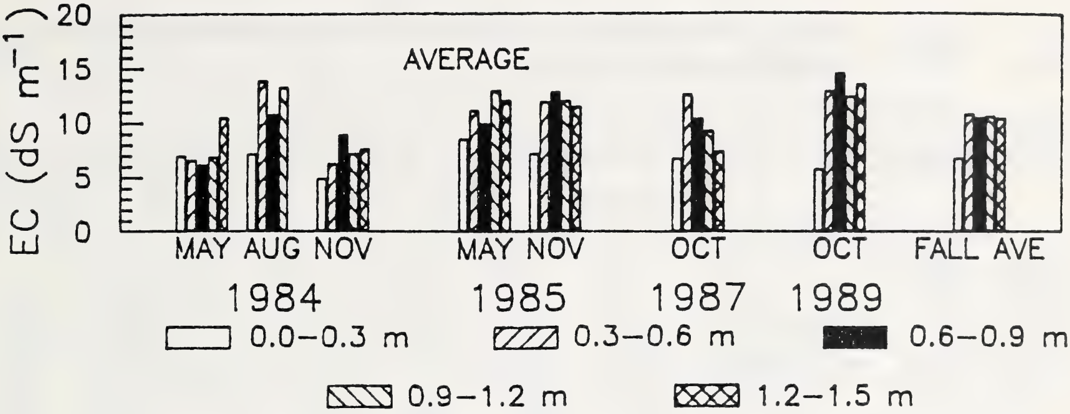


Fig. 2. Cont'd



EC (dS m^{-1})
20
15
10
5
0
AVERAGE
MAY AUG NOV
1984
MAY NOV
1985
OCT
1987
OCT
1989
FALL AVE
0.0–0.3 m
0.3–0.6 m
0.6–0.9 m
0.9–1.2 m
1.2–1.5 m

Table 1. Salinity measurements as EC in dS m^{-1} for nine sampling points at Site 1 and five sampling points at Site 2

SITE 1		1984			1985		1987	1989	
SAMPLE POINT	DEPTH (m)	MAY 15	AUG 7	NOV 7	MAY 14	NOV 7	OCT 30	OCT 27	FALL AVE.
1	0.0-0.3	8.3	5.0	7.8	3.9	1.7	5.6	1.9	4.3
	0.3-0.6	4.6	10.1	6.4	8.4	8.3	7.7	8.3	7.7
	0.6-0.9	9.3	8.6	7.2	6.0	7.8	9.5	11.4	9.0
	0.9-1.2	19.1	11.6	11.4	10.6	11.1	8.9	14.4	11.5
	1.2-1.5	12.9		9.7	9.7	14.5	16.4	12.7	13.3
2	0.0-0.3	12.0	10.7	7.4	7.8	10.9	6.8	9.0	8.5
	0.3-0.6	13.8	11.3	12.3	7.5	13.3	12.8	13.4	13.0
	0.6-0.9	5.6	11.0	8.0	6.0	4.6	4.9	9.4	6.7
	0.9-1.2	7.5	10.7	8.8	10.9	10.0	7.4	9.7	9.0
	1.2-1.5	13.5		8.1	8.7	8.8	16.7	12.1	11.4
3	0.0-0.3	5.1	3.8	1.2	1.4	4.1	1.3	3.6	2.6
	0.3-0.6	10.8	9.2	8.5	8.7	10.2	7.4	7.7	8.4
	0.6-0.9	11.9	10.7	8.6	11.2	10.5	11.6	14.8	11.4
	0.9-1.2	7.8	8.9	6.9	10.9	9.9	13.4	10.4	10.1
	1.2-1.5	9.9		6.4	10.0	8.9	10.1	9.7	8.8
4	0.0-0.3	3.6		1.4	1.7	2.0	2.0	2.2	1.9
	0.3-0.6	10.9		5.0	10.9	12.0	4.2	1.9	5.8
	0.6-0.9	13.1		11.9	16.7	13.6	14.6	2.2	10.6
	0.9-1.2	14.4		9.7	15.8	12.0	11.0	2.9	8.9
	1.2-1.5	13.7		8.0	16.4	10.8	10.4	8.0	9.3
5	0.0-0.3	7.7	4.4	1.2	2.6	2.6	6.8	2.6	3.3
	0.3-0.6	1.7	2.9	1.3	2.0	3.6	6.5	6.3	4.4
	0.6-0.9	2.6	2.9	2.3	3.9	7.4	6.5	7.3	5.9
	0.9-1.2	8.1	10.1	13.9	5.7	10.8	10.4	10.0	11.3
	1.2-1.5	8.8		7.0	9.4	10.0	9.2	8.7	8.7
6	0.0-0.3	2.3	2.9	1.4	1.7	1.9	2.9	2.9	2.3
	0.3-0.6	9.9	5.3	5.0	7.5	5.5	4.7	4.9	5.0
	0.6-0.9	15.8	11.3	9.2	14.2	12.0	11.6	12.1	11.2
	0.9-1.2	12.8	12.5	8.5	12.4	12.0	11.0	11.7	10.8
	1.2-1.5	13.1		8.6	12.4	10.9	14.3	13.1	11.7

SITE 1 - Cont'd		1984			1985		1987	1989	
SAMPLE POINT	DEPTH (m)	MAY 15	AUG 7	NOV 7	MAY 14	NOV 7	OCT 30	OCT 27	FALL AVE.
7	0.0-0.3	1.7	2.9	10.2	2.3	1.4	2.0	1.9	3.9
	0.3-0.6	9.2	12.2	7.5	5.7	3.1	9.5	7.3	6.9
	0.6-0.9	2.5	8.0	2.2	1.4	1.4	2.0	1.5	1.8
	0.9-1.2	3.3	5.9	2.9	3.6	2.6	3.2	2.6	2.8
	1.2-1.5	2.6		2.8	2.6	2.9	3.2	2.6	2.9
8	0.0-0.3	3.2	2.6	7.5	2.3	1.8	2.4	2.2	3.5
	0.3-0.6	2.3	2.9	1.7	1.7	2.5	2.6	4.6	2.9
	0.6-0.9	1.8	2.0	2.0	1.4	1.7	1.7	2.2	1.9
	0.9-1.2	1.3	2.0	1.6	1.1	1.4	1.4	1.9	1.6
	1.2-1.5	1.3		1.4	1.1	1.3	1.4	1.9	1.5
9	0.0-0.3	1.9	2.6	1.5	1.7	2.1	2.2	2.6	2.1
	0.3-0.6	2.0	2.6	2.1	2.0	3.4	2.3	2.9	2.7
	0.6-0.9	2.3	2.6	4.4	2.0	2.1	2.6	2.6	2.9
	0.9-1.2	3.3	3.2	8.8	2.9	1.8	17.6	10.4	9.6
	1.2-1.5	9.3		8.6	5.7	5.0	17.6	14.4	11.4
AVE	0.0-0.3	5.1	4.3	4.4	2.8	3.2	3.6	3.2	3.6
	0.3-0.6	7.3	7.0	5.5	6.1	6.9	6.4	6.4	6.3
	0.6-0.9	7.2	7.1	6.2	7.0	6.8	7.2	7.1	6.8
	0.9-1.2	8.6	8.1	8.0	8.2	8.0	9.4	8.2	8.4
	1.2-1.5	9.5		6.7	8.4	8.1	11.0	9.2	8.8

SITE 2		1984			1985		1987	1989	
SAMPLE POINT	DEPTH (m)	MAY 15	AUG 7	NOV 7	MAY 14	NOV 7	OCT 30	OCT 27	FALL AVE.
1	0.0-0.3	5.7	11.1	7.5	10.3	7.9	8.5	2.6	6.6
	0.3-0.6	7.2	14.2	3.7	8.9	11.2	15.0	10.5	10.1
	0.6-0.9	6.2	8.8	10.5	5.5	12.6	9.8	16.7	12.4
	0.9-1.2	5.8	14.0	4.1	14.5	9.1	12.7	12.9	9.7
	1.2-1.5	12.2		6.3	9.2	12.4	8.3	12.9	9.9
2	0.0-0.3	5.6	4.9	5.2	8.1	5.1		2.0	4.1
	0.3-0.6	7.2	9.3	8.0	15.8	17.0		13.2	12.7
	0.6-0.9	4.4	6.7	5.2	9.7	13.4		12.6	10.4
	0.9-1.2	4.5	3.3	3.6	8.7	14.0		10.8	9.5
	1.2-1.5	4.2		3.2	5.8	10.3		14.4	9.3
3	0.0-0.3	6.4	2.8	2.0	5.8	4.7	5.4	1.7	3.5
	0.3-0.6	8.5	17.3	9.8	13.4	11.6	15.3	11.7	12.1
	0.6-0.9	9.6	14.2	9.5	13.7	13.5	7.5	15.2	11.4
	0.9-1.2	8.4	15.0	9.7	14.5	12.6	12.4	12.3	11.8
	1.2-1.5			9.3	17.4	11.0	10.8	14.4	11.4
4	0.0-0.3	8.9	9.5	2.0	15.3	15.6	13.7	13.5	11.2
	0.3-0.6	4.9	17.1	6.3	6.8	14.0	18.9	15.5	13.7
	0.6-0.9	4.8	14.0	10.2	6.8	12.2	16.6	15.2	13.6
	0.9-1.2	11.0	16.0	9.1	12.7	11.6	11.1	11.4	10.8
	1.2-1.5	11.8		9.8	15.6	12.4	9.3	13.8	11.3
5	0.0-0.3	8.6	7.5	7.9	3.1	2.7	6.2	9.4	6.5
	0.3-0.6	5.2	11.4	3.9	10.3	6.0	14.0	13.5	9.3
	0.6-0.9	6.2	10.3	9.1	14.0	12.2	18.4	12.6	13.1
	0.9-1.2	4.9	18.1	9.7	14.2	12.6	10.3	14.4	11.7
	1.2-1.5	14.0		9.3	12.1	11.3	8.5	12.0	10.3
AVE	0.0-0.3	7.0	7.2	4.9	8.5	7.2	6.8	5.8	6.8
	0.3-0.6	6.6	13.9	6.3	11.1	11.9	12.6	12.9	10.8
	0.6-0.9	6.2	10.8	8.9	9.9	12.8	10.4	14.5	10.5
	0.9-1.2	6.9	13.3	7.2	12.9	12.0	9.3	12.4	10.6
	1.2-1.5	10.5		7.6	12.0	11.5	7.4	13.5	10.4

SOIL MOISTURE IN RECHARGE AND DISCHARGE ENVIRONMENTS UNDER VEGETATIVE MOISTURE CONTROLS

R. Heywood[1], Hank Vander Pluym[2], Joe Michielsen[3]

INTRODUCTION

Vegetative controls are being used in Alberta to control dryland salinity. These applications have been based on experience in Montana (Brown, et al, 1983) and the observation that dryland salinity is less a problem in native grass than cropped areas. Since the crop fallow rotation has been implicated in the development of dryland salinity (Christie, et al, 1985) both annual cropping (cereals and oilseeds), and deep rooted perennial crops have been proposed for control (Vander Pluym, 1985).

In this project, three sites were selected for study, one each in the Brown, Dark Brown and Black Soil Zone. Soil moisture monitoring was performed at several locations along transects leading from the recharge to the discharge environment. At each site the effectiveness of alfalfa in extracting soil water was to be compared to that of annual crops seeded each spring.

The sites were all established on operating farms with the co-operation of the land owners. Changes to the studies related to the economics and environmental realities of the study period were anticipated and have occurred.

METHODS

General

The study sites are located as follows:

Soil Zone	Farmer Name	Location	Text Reference
Brown	D. Walsh	N.E.33-3-12-4 N.W.34-3-12-4	Foremost site
Dark Brown	R. Svanes	S.E.18-13-21-4	Carmangay site
Black	Nordstrom	S.W.1-48-13-4	Viking site

Alfalfa was under-seeded with a nurse crop at the Walsh and Svanes sites in 1985 and in 1986 at Nordstrom. Financial assistance was provided by SCAP (Soil Conservation Area Program) at the Walsh and Svanes site and under Farming for the Future (project #84-0409) at the Nordstrom site.

Soil moisture was monitored by the neutron attentuation method utilizing calibrated PVC access tubing. The access tubing was installed to the water table depth or 4 metres whichever was least. Tube installation occurred in June, 1986 and monitoring commenced at that time and continued until the fall of 1989. Readings at the Foremost and Carmangay site were taken twice monthly and those at Viking monthly during the growing season.

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Readings were taken as weather permitted in the recharge periods. Calculation of soil moisture use are based on peak spring soil moisture and the minimum found in the growing season. Recharge between growing seasons is based on aforementioned minimum moisture and the maximum stored moisture recorded the next spring.

RESULTS

Foremost Site

This project looked at reduction of soil moisture in land producing alfalfa and that of producing annual crops. In all cases several processes including crop use, drainage and rewetting from water tables are occurring. Opinions of what produced the soil moisture charges reported are given. The data supports these opinions as does water tables collected by others (data is not presented in this report as it has not been fully analyzed).

Table 1 indicates use of soil moisture by growing season, total recharge and the net moisture use between June, 1986 and August, 1989. "a", "g", "w" and "f" indicate alfalfa, grass, wheat and fallow in each year. The general groundwater situation existing at each site is indicated as to whether it has recharge or discharge.

Alfalfa appears to extract moisture to the depth of three metres in upland environments. At the margin of the seep, alfalfa was less effective in extractions of soil moisture. Water table levels decreased during the study period. Alfalfa was more effective in using soil moisture than the cereal grains. The fallow year in 1989 appeared to negate any value of continuous cropping for three years. (See Table 1).

Carmangay Site

Alfalfa and annual crops were compared for ability to reduce soil moisture. The annually seeded areas was seeded to alfalfa with a nurse crop in 1985. The area surrounding the monitoring site remained in weeds. "a", "b", and "w" indicate alfalfa, barley and weed respectively. The general groundwater conditions indicate as to whether it was recharge or discharge. Table 2 indicates the use of soil moisture by year, total recharge and net moisture use from June, 1986 until August, 1989. (See Table 2).

At this location both alfalfa water use and drainage appears to be occurring. Crop use appears to be occurring to at least three metres. Drainage is suggested by the fact that soil moisture decreases in the two to three metre depth during the recharge period (winter). This is supported by the fact that water table level decreased during the study period.

The drainage factor appeared to have a greater impact on net moisture change near the discharge zone than in the site farther upslope.

Viking Site

At Viking part of the recharge area was seeded to alfalfa and part to annual crops (one year fallow), but the discharged areas was seeded to barley annually.

Table 3 indicates the soil moisture that occurred each growing season, the total recharge in 86-87, 87-88 and 88-89 recharge periods. "c", "a", "b" and "f" indicates the production of canola, alfalfa, barley, wheat and fallow in each of the growing seasons.

The net moisture use was greatest in the area seeded to alfalfa. In the three out of four monitoring sites, drainage appears to occur during the winter. Crop use seemed to dominate above two metres, but drainge below two metres.

In general the annual crop in the recharge zone led to an increase in soil moisture over the study period. Generally moisture decreased below two metres between growing seasons. In the summer of 1988 the summerfallow appeared to increase moisture at most depths.

The discharge area had virtually no change in soil moisture levels during the study period below 0.5 metres (data is given for 0-1 metre depth). Moisture actually increased at one site.

CONCLUSIONS

Alfalfa provided greater soil moisture extraction and a greater depth of extraction than annual cereal or soilseed cropping. Alfalfa use to three metres in upland locations appeared to occur in both the Brown and Dark Brown Soil Zones. In Black Soil Zone extraction to only two metres appeared likely.

Alfalfa appeared to be less effective in depletion of deep seated moisture near the margins of the discharge zone than in the upland locations.

Introducing a fallow year in the annual cereal rotation appeared to negate any positive benefit in soil moisture extraction achieved up to that time.

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Table 1. Change in Soil Moisture - Foremost Site

	Crop Use in Growing Season 1986	1987	1988	1989	Total Recharge in 1986-89	Reduction in Soil Moisture June 86 - Aug. 89
Hole 777 (a.a.a.a) recharge area						
0 - 1 m	88.9	129.6	13.2	69.8	162.3	139.2
1 - 2 m	4.4	31.2	23.2	10.1	0	68.1
2 - 3 m	0	6.2	14.8	(8.6)	5.1	7.3
3 - 4 m	NA	NA	(5.8)	1.1	(6.2)	1.5
Hole 778 (a.a.a.a) recharge area						
0 - 1 m	10.9	92.3	0	148.8	238.9	13.0
1 - 2 m	4.4	41.3	31.9	51.4	30.6	98.4
2 - 3 m	0	0	4.3	5.2	8.7	0.8
3 - 4 m	NA	NA	0	(3.6)	5.4	(9.0)
Hole 779 (a.a.a.a) recharge area immediately next to discharge area						
0 - 1 m	16.4	54.9	21.8	42.4	113.7	21.8
1 - 2 m	0	(4.8)	(4.1)	(11.6)	30.9	(51.4)
2 - 3 m	(4.2)	13.7	10.1	4.9	12.3	122
Hole 780 (9.9.9.9) upper edge of discharge area						
0 - 1 m	30.2	69.7	0	42.4	130.2	12.1
1 - 2 m	0	10.3	(7.2)	(6.4)	(10.4)	7.3
2 - 3 m	0	0	6.4	(3.0)	8.9	(5.5)
Hole 781 (9.9.9.9) discharge area						
0 - 1 m	9.3	13.9	0	35.0	28.5	6.5
Hole 789D (w.w.w.f) recharge area						
0 - 1 m	0.7	70.4	12.3	90.0	158.5	24.9
1 - 2 m	(68.3)	12.3	6.8	(14.2)	26.3	(89.4)
2 - 3 m	0	(5.4)	0	(-2.6)	0	(8.0)
Hole 789C (w.w.w.f) recharge area						
0 - 1 m	10.9	78.5	15.3	(14.6)	80.8	9.30
1 - 2 m	0	0	(5.8)	6.0	6.6	(6.4)
2 - 3 m	0	4.3	0	(12.8)	(14.0)	5.5
Hole 789B (w.w.w.f) discharge area						
0 - 1 m	17.7	160.9	102.7	(27.0)	137.5	116.8
1 - 2 m	0	28.1	12.5	(39.4)	(8.6)	9.8
2 - 3 m	0	6.4	7.9	(26.2)	21.1	(21.1)
Hole 789A (w.w.w.f) discharge area						
0 - 1 m	18.7	63.3	67.2	(2.2)	111.6	35.35
1 - 2 m	0	3.0	(9.9)	(3.8)	(20.3)	5.65
2 - 3 m	(5.8)	(9.4)	0	(7.1)	(9.5)	(12.8)

Table 2.Changes in Soil Moisture - Carmangay Site

Observation Site	Growing Season Crop Use 1986	1987	1988	1989	Total 1986-89	Total Moisture Recharge Change 1986 - 1989
Hole 1 (a.a.a.a) recharge area						
0 - 1 m	3.3	98.9	069.8	29.7	104.4	29.2
1 - 2 m	0	33.3	38.5	8.23	14.3	107.8
2 - 3 m	(5.7)	111.3	20.7	3.4	(7.3)	137.0
3 - 4 m	--	--	--	16.9	--	16.9
Hole 2 (a.a.a.a) recharge area						
0 - 1 m	4.2	122.3	5.5	1.8	83.4	50.7
1 - 2 m	24.0	78.8	28.6	(6.5)	(14.2)	139.1
2 - 3 m	(3.0)	80.9	18.6	8.6	(6.8)	109.9
3 - 4 m	--	--	--	17.6	--	17.6
Hole 3 (a.a.a.a) recharge area						
0 - 1 m	16.4	104.2	0	6.8	46.7	81.2
1 - 2 m	8.4	94.5	37.0	4.1	3.2	140.8
2 - 3 m	0	42.7	11.0	4.5	(30.0)	88.8
3 - 4 m	--	--	--	24.0	--	24.0
Hole 4 (a.a.a.a) recharge area approaching discharge area						
0 - 1 m	0	161.6	(2.8)	53.6	159.3	33.1
1 - 2 m	24.5	131.2	37.5	9.8	(17.0)	239.0
2 - 3 m	28.8	182.4	132.2	21.0	61.9	302.3
3 - 4 m	--	--	--	(9.4)	--	(9.4)
Hole 5 (b.b.w.w) recharge area approaching discharge area						
0 - 1 m	(6.8)	68.1	33.7	25.5	66.2	77.10
1 - 2 m	0	74.9	9.3	(1.5)	(7.1)	90.00
2 - 3 m	9.6	118.3	48.3	(1.9)	(18.8)	193.50
3 - 4 m	--	--	--	(3.0)	--	(3.0)

Table 3 Changes in Soil Moisture - 1986 - 1989 - Viking Site

Observation Site	Growing Season Crop Use 1986	1987	1988	1989	Total Recharge 1986-89	Reduction Soil Moisture 1986 - 1989
Recharge Area - Alfalfa						
Hole 1 (c,a,a,a)						
0 - 1 m	(120)	16.7	114.3	85.5	128.7	75.80
1 - 2 m	0	0	51.2	37.9	13.8	73.3
2 - 2.75 m	(6.4)	0	5.1	1.1	(13.9)	13.7
Hole 2 (c,a,a,a)						
0 - 1 m	(12.9)	71.2	48.9	62.2	110.10	59.3
1 - 2 m	(6.5)	0	14.6	(2.6)	(11.2)	16.7
2 - 3 m	(3.7)	37.4	107.5	9.75	(91.6)	242.6
Hole 3 (c,a,a,a)						
0 - 1 m	(3.1)	59.3	159.9	57.4	107.1	166.6
1 - 2 m	8.7	0	6.1	4.9	2.3	21.9
2 - 2.25 m	5.1	0	0	4.1	(7.1)	16.3
Hole 4 (c,a,a,a)						
0 - 1 m	59.4	43.4	128.3	119.2	172.0	178.3
1 - 2 m	7.8	0	198	2.2	(33.1)	62.9
2 - 3 m	5.1	0	4.1	(15.8)	(31.2)	24.6
Discharge Area - Annual Crop						
Hole 5 (c,b,b,c)						
0 - 1 m	20.7	36.6	49.8	58.9	82.1	83.9
1 - 1.5 m	6.0	0	4.1	(3.4)	(33.3)	40.0
Hole 6 (c,b,b,c)						
0 - 1	4.1	4.1	99.8	75.4	102.50	80.9
1 - 1.75	0	0	4.2	8.6	13.00	(0.2)
Hole 11 (c,b,b,c)						
0 - 1	14.9	8.8	0.8	3.75	57.6	(29.35)
Hole 12 (c,b,b,c)						
0 - 1	40.6	5.1	51.5	68.6	132.1	33.7
1 - 1.5	25.3	0	0	-	-	-
Recharge Area - Annual Crop						
Hole 7 (c,b,b,c)						
0 - 1	10.6	1.98	(4.1)	-	95.8*	69.5*
1 - 2	0	0	4.6	-	0.1	4.5
2 - 2.5	0	(9.9)	(36.0)	-	22.3	68.2
Hole 8 (c,b;b,c)						
0 - 1	9.9	25.4	1.8	55.1	172.4	(80.2)
1 - 2	29.0	27.2	(13.7)	-	(32.6)	9.9
1 - 2.5	5.1	0	55.1	-	(32.8)	27.4
Hole 9 (c,w,f,c)						
0 - 1	52.0	28.5	(79.1)	(12.0)	112.4	(12.3)
1 - 2	12.8	11.5	(12.3)	22.5	92.1	(57.6)
2 - 3	(4.6)	(6.8)	(20.4)	(24.4)	(41.9)	(14.3)
Hole		10		(c,w,c,c)		
0 - 1	7.4	11.3	(6.4)	93.8	285.0	(178.7)
1 - 2	0	(4.1)	0	(26.6)	25.3	(56.0)
2 - 2.75	0	0	(8.7)	(2.6)	(19.4)	8.2

* indicates recharge for 86-88 period

COMPARISON OF VARIOUS SNOW MANAGEMENT PRACTICES IN CENTRAL AND SOUTHERN ALBERTA

A. E. Howard and J. Michielsen[1]

INTRODUCTION

Snow management is considered one of the most feasible ways for dryland agriculture producers to increase the amount of soil moisture that is stored during the non-growing season. Additional stored soil moisture will contribute to increased yields, better seedling emergence, more effective use of fertilizer, and increased tolerance to periods of drought. The snow management study was initiated by R.T. Heywood in 1986, and has been continued on a yearly basis since that time. This report summarizes the activities and results during the winter of 1989-90.

SITE DESCRIPTION

Co-operating producers were approached during August and September of 1989 and asked to participate in the study. A total of 9 sites were then established and instrumented, seven located on stubble, and two on forage fields. Comparisons between bare fields and short (conventionally-cut) stubble could be made on three of the stubble sites, and comparisons between conventionally-cut and alternate height stubble could be made on five of the sites, with one site providing comparisons for both bare fields and alternate stubble heights. One site also had barrier strips of flax seeded into fallow during July of 1989. The two forage sites were established to evaluate the effectiveness of leave strips from the final cut at increasing the amount of stored soil moisture from trapped snow. The site locations and the nature of the snow management practices are identified in Table 1. In each case snow management practices reflected the normal farming operation of the cooperator, and the practices are typical for snow management in that region. Control over the plot design was limited since harvesting operations had already been completed at most sites, and because some producers preferred to have only one type of snow management practice on a field. As a result different fields were used for different treatments in some cases.

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Table 1. Site locations and snow management practices studied during 1989-90.

AREA	LOCATION	TREATMENTS
Barons	S - 1-13-22-W4	bare fallow; flax strips on fallow; barley stubble, spiked rye stubble
Foremost	SE-19- 6-11-W4	conventional stubble; alternate height stubble
Claresholm	SW- 2-12-26-W4	conventional stubble; alternate height stubble; bare field
Claresholm	NE- 2-12-26-W4	conventional stubble; alternate height stubble (using deflectors)
Milk River	SE-24- 2-13-W4	conventional stubble; alternate height stubble
Forestburg	SW-21-41-13-W4	conventional stubble; alternate height stubble (Wilger Stripper)
Halkirk	SE-13-40-16-W4	bare field; conventional stubble
Viking	NW-25-48-13-W4	forage strips
Castor	NW-14-38-15-W4	forage strips

METHOD

Sites were sampled for soil texture prior to instrumentation, and neutron probe access tubes were then installed in replicates of three per treatment at each site. Soil moisture was monitored monthly from the date of installation until March, 1990, then every two weeks until the end of April. Soil moisture was measured at depths of 25, 50, 75, and 100 cm. Snow accumulation was also measured when applicable during each monitoring event. A montrose snow core sampler, obtained on loan from Alberta Environment, was used to measure snow depth and density. These measurements could be converted to water equivalent.

RESULTS

Above-normal precipitation during the late summer and fall increased the soil moisture levels prior to freeze-up, and moisture gains from snowmelt the following spring became difficult to observe. This was especially evident in the central Alberta sites. Overwinter soil moisture measurements show however, that a small but consistent increase in the amount of soil moisture stored in the fields where stubble was left standing. The amount of increase varied from 12 to 21 mm (0.5 to 0.8 inches) for conventionally-cut stubble over bare fields. Comparisons of alternate height strips to conventionally-cut heights of stubble showed that in the southern Alberta sites the fields with alternate height stubble had an increase in stored soil moisture ranging from negligible to 16mm (0.6 inches) over that gained under conventionally-cut stubble. In central Alberta the alternate height strips gained essentially no more soil moisture than did the conventionally-cut stubble. The one site that had a barrier strip of flax showed no more increase in stored soil moisture than that of the bare field to which it was compared. The snow collection data suggested a strong correlation between the amount of snow trapped and the amount

of soil moisture gained, indicating that those areas where only marginal gains were observed likely had insufficient snowfall to allow the alternate height strips to trap more snow than the conventionally-cut stubble. The low snowfall is also a factor in the apparent ineffectiveness of the flax barrier strips. The forage sites did not show any benefit to soil moisture storage, however these sites did not have a suitable control site available, and the data should not considered a reliable basis for conclusions. Overwinter soil moisture gains are presented for the stubble sites in Tables 2 and 3.

Table 2. Soil moisture gains under bare fields, conventionally-cut stubble, and barrier strips of flax during the winter of 1989-90.

AREA	LOCATION	SOIL MOISTURE GAIN (mm)		
		BARE FIELD	STUBBLE	FLAX STRIPS
Barons	S - 1-13-22-W4	11.8	27.5	13.3
Claresholm	SW- 2-12-26-W4	0	21.2	
Halkirk	SE-13-40-16-W4	4.2	16.7	

Table 3. Soil moisture gains under conventionally-cut stubble, and alternate height stubble during the winter of 1989-90.

AREA	LOCATION	SOIL MOISTURE GAIN (mm)	
		CONVENTIONAL	ALTERNATE HEIGHT
Claresholm	SW- 2-12-26-W4	15.7	19.8
Claresholm	NE- 2-12-26-W4	21.2	23.7
Foremost	SE-19- 6-11-W4	20.2	20.0
Milk River	SE-24- 2-13-W4	0	16.5
Forestburg	SW-21-41-13-W4	13.3	14.6

The montrose snow sampler was used for the first time this winter and was ineffective at providing reliable density readings; therefore only snow depth data was analyzed. The coring unit is designed for mountain conditions and does not appear to be sensitive enough to be used in areas of low snowfall, which applies to the site locations for this study. Density and water equivalent data of the snowpack at each site is not available.

CONCLUSIONS

The effectiveness of snow management is dependent upon many climatic variables, and because of climatic variability it is difficult to evaluate the effectiveness of any given snow management technique on a year to year basis. The results of 1989-90 are generally consistent with the concept that snow management practices provide more overwinter soil moisture gains. The magnitude of the gains during 1989-90 is low compared to many of the published studies, but similar to some of the gains observed during earlier years of this study. Snow management requires evaluation over a long period of time and results should be

expressed with some degree of probability. Comparisons should also be made where there is strong control over the site layout.

The results reinforce the idea that any stubble left standing will increase the amount of overwinter soil moisture storage. Where sufficient snow was available, alternate height stubble increased soil moisture reserves to an even greater degree. The evaluation of flax barrier strips is inconclusive due to the very low amount of snow that fell at that site. Snow management appears to be most promising for the central portion of the province whereas in the chinook zone, gains from snow management are likely the most variable. More research is required in all regions to determine the most effective snow management techniques and to assess the probability of receiving acceptable soil moisture gains, however the need is particularly crucial for the chinook zone.

SNOW MANAGEMENT 1987-88 AND 1988-89

R. T. Heywood[1], Don Wentz[2], Joe Michielsen[3]

INTRODUCTION

Snow management provides a method of increasing soil stored moisture between growing season for subsequent crop growth. In general, a 25 mm increase in crop water use will result in a yield increase equivalent to 4 bushels/acre of hard red spring wheat and may permit annual cropping in the Brown and Dark Brown Soil zones.

In this study the ability of deflector cut strips of tall stubble, unharvested grain strips, alternatively tall and short cut stubble, and uniformly tall stubble were observed. This project received funding from the "On Farm Demonstration Program" (Project 84-E006-1).

METHODS

Sites were selected in fields of farmers using snow management to increase soil moisture. Normally harvest areas were selected as control whenever possible. At each site neutron access tubes were installed during the fall. Moisture was monitored at 0.25, 0.50, 0.75 and 1.0 metre depths by the neutron attenuation method. Measurements were taken at the time of tube installation and periodically during fall and winter. Tubes were removed in April.

Precipitation data was taken from the site nearest the farm listed in the western and northern climate summaries prepared by Atmospheric Environment Service (western region), Environment Canada.

RESULTS

Precipitation between the 1987-88 growing season was 40 to 60% of normal. Table 1 indicates the storages obtained.

In the 1988-89 storage period precipitation varied from 30% of normal in Bow Island to near normal in the western area (Pincher Creek-Lethbridge). Table 2 indicate the levels of storage obtained.

Snow management under low levels of overwinter precipitation (87-88) appeared to make small positive contributions to soil moisture. Under more average conditions 1988-89, contributions increased to 25 mm or more.

A number of factors appear to influence storage. The direction of harvest should be across prevailing wind direction so that the barrier strips can intercept snow. Exposed hill sides will catch less snow and accumulate less soil moisture than level field area.

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[2] Provincial Soil Specialist, Conservation & Development Br., Lethbridge

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If soil moisture storage effiencies are calculated, values obtained are similar to those reported at Swift Current.

TABLE 1 - OVER WINTER STORAGE OF SOIL MOISTURE (MM) 1987-88

Deflector Harvested

Site	Control	Treatment
Foote	no difference	
Blunt	9.2	6.7
Svanes		
north/south strip	6.8	10.1
east/west strip	6.8	10.1
Opp	3.2	8.5

Alternative Swathing Height

Site	Control	Tall	Short
Bjorn	3.5	8.6	3.8
Helwig			
north/south strip	16.9	16.0	9.0
east/west strip	16.9	6.9	-
Wehlage			
bottom of hill	24.0	32.4	26.3
top of hill	1.2	24.4	21.3
Opp	5.9	8.1	13.6
Matheson - level	18.5	18.5	36.2
- hill	-	22.2	15.7

TABLE 2 - OVER WINTER STORAGE OF SOIL MOISTURE IN MM 1988-89

(a) Deflector and unharvested strips

Site	Control	Treatment
Opp		
east/west strip	77.0	48.0
north/south strip	77.0	90.0
Svannes (unharvested)		
north/south strip	14.4	58.4
Foote (unharvested)		
north/south strip	-	-
Exposed location	-	68.4
Level location	-	68.4

(b) Alternative Height Swathing Fallow

Walsh			
exposed location	22.4	26.0	36.4
level location	34.2	105.9	91.6
Wehlage			
exposed location		43.2	49.6
level location	-	49.6	64.0
Bjorn	26.9	36.4	53.8

(c) Tall stubble field vs. normal stubble

Sproule normal subble 54.1 - Stubble 72.5

CONCLUSION

Snow management methods provided a method of increasing soil moisture available for later crop use. Under near average conditions in 1988-89 storage of 25 mm of additional moisture was common. Under/over precipitation levels (50% of normal) storages were low but generally positive.

MOISTURE OVER WINTER STORAGE EFFICIENCY ON STUBBLE LAND 1988-89

R. T. Heywood[1], J. Michielsen[2]

INTRODUCTION

Stubble soil moisture storage between harvest and the next spring is significant to crop production on annually cropped land. Few areas receive sufficient growing season precipitation to equal crop need nor is it distributed as required. Soil stored moisture reduces the stress from both the lack of precipitation and its poor distribution. The ability to store enough moisture between harvest and spring to generally produce an acceptable crop determines the division between the annual cropped and summer fallow areas.

This project records the storage level achieved between early October, 1989 and the end of April, 1989 at a large number of sites across Alberta.

METHODS

Soil moisture data was collected to compile fall and spring soil moisture maps. The sames sites within the selected fields were sampled each time. Soil moisture was identified by the hand feel method to a depth of 1.0 metre.

Precipitation data from the "Western and Northern Climate Summary" prepared by Scientific Service Division of Atmospheric Environment Service Western Region, Environment Canada, was used to prepared provincial precipitation map to indicate precipitation levels at each site. The amount of soil moisture stored was estimated at each site and a storage efficiency estimate. These values were combined to give values for each soil zone.

In the case of the southern area the zones were subdivided as south or north of the Bow River. This was done because differences appeared in the data and because Alberta Soil and Feed Testing divides the soil zones at the Bow River for fertility recommendations.

RESULTS

Table 1 indicates the soil zone, the number of sites, the moisture stored and percentage of precipitation stored.

Further subdivision suggested that weather conditions during the storage period could be related to storage levels obtained.

Storage levels in the Dark Brown and Brown Soil zones south of the Bow River appeared lower than reported in literature. Precipitation levels in these zones were generally below normal. Precipitation storage was somewhat greater than expected in the other soil zones.

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[2] Water Management Technologist, Cons. & Dev. Branch, Lethbridge

TABLE 1 - Soil Moisture Storage 1988-89

Soil Zone	No. of Sites	Ave. Prec. Stored mm	Ave. Storage Prec. %
Brown Soil-S.Bow River	13	20	19
Brown Soil-N.Bow River	6	13	21
Dark Br.Soil-S.Bow River	16	32	27
Dark Br.Soil-N.Bow River	26	33	36
Thin Bl.Soil-S.Bow River	12	68	44
Thin Bl.Soil-N.Bow River	23	47	49
Black Soil	19	45	42
Grey Wooded Soil-Wes.Area	23	45	35
Grey Wooded Soil-Eas.Area	13	48	61
Peace River Area	22	54	43

CONCLUSIONS

During the winter of 1988-89 precipitation varied by soil zone. Environmental factors such as chinooks, late pre-freeze precipitation, a slow spring melt appeared to impact on storage.

EVALUATION OF THE DAMMER DIKER FOR INCREASING SOIL MOISTURE AND YIELDS IN SOUTHERN ALBERTA

A. E. Howard and J. Michielsen[1]

INTRODUCTION

The Dammer-Diker (TM) is an implement designed to improve soil moisture storage by ripping the soil to improve infiltration and pocketing the surface to retain more water. It has been used primarily on irrigated land, however in dryland areas subject to moisture shortages and slowly-permeable soils, much interest has been directed toward the potential of the Dammer-Diker to improve crop production. If overwinter precipitation can be utilized to improve spring soil moisture levels, the need for summerfallow is reduced and any increase in yield and corresponding increase in residue provides the opportunity for better soil cover. Demonstrations with the dammer-diker have shown that crops with higher yields and more vegetative growth were produced on the treated portions of the field. Questions have arisen as to how consistent these benefits are, and whether they are due to the ripping action alone, or the combined effect of ripping and surface water detention, or other causes. This project was initiated in August of 1990 and is intended to continue until 1993. This report summarizes the activities of the initial stages of the project.

SITE DESCRIPTION

Ths site for this study is located east of Wrentham, Alberta, approximately 70 km southeast of Lethbridge (Figure 1). The area contains Orthic Brown Chernozemic soils mapped as Maleb-Cranford, and inspection of cores indicated that the soils were derived from glacial till. The plots are located in NE 3- 7-15-W4, a field that has 3-year wheat, 1-year fallow rotation. The field has undulating topography.

METHOD

The study has three objectives:

1. to evaluate the effect of the dammer-diker on improving the amount of available soil moisture and crop yield.

2. to acertain whether any benefit to the crop occurs as a result of the ripping or the increased detention of surface water from the pocketing of the soil.

3. to identify the costs associated with operating a dammer diker and relate those to any added income from the land during the study period.

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[1]Farm Water Management Section, Conservation and Development Branch, Lethbridge

Statistically, the study was designed to test the following hypotheses:

1. There is no difference in available soil moisture or yield among plots treated with the Dammer-Diker and those left untreated

2. There is no difference in available soil moisture or yield between those plots that were ripped and pocketed with the dammer diker and those plots that were ripped and not pocketed.

The field was divided into twelve plots in which two treatments and a control (untreated) were replicated four times. The plot layout is illustrated in Figure 2. The treatments with the dammer diker included a set of plots that were both ripped and pocketed (T1), and a set that was ripped, but not pocketed (T2). It is the opinion of the authors that the visible improvements in crops on fields treated with the dammer-diker during demonstrations were primarily due to the ripping action, and that the pocketing of the soil produces a much lesser benefit. The study was therefore designed to include a set of treatments in which the dammer diker ripped the soil, but the paddles were not used.

Once the treatments were applied, one neutron probe acces tube was then installed in each plot. The tubes were installed in the high level portions of each plot, and located between the ripping tracks. The access tubes provide the capability to monitor soil moisture to 120 cm depth, and can be modified to remain below the ground surface to accomodate farm operations on the plots. Soil samples were obtained from the cores where the tubes were installed. The samples are to be analyzed for texture, salinity, pH, and will also be used to support fertility samples that will be obtained during the spring of 1991.

Rainfall data is currently being collected at the farm site, and records are available for the past fifteen years. Soil temperature sensors and a snow gauge are scheduled for installation. Plot management and cropping will be performed by the producer.

RESULTS

Because of the extremely dry soil conditions at the time the treatments were applied the paddles controlled the depth of ripping on the ripped and pocketed plots by holding up the unit and restricting the penetration of the rippers to 25 cm. At the plots which were ripped only, the ripper penetration was manually controlled in order to maintain the same ripping depth. This added to the operation time. Overwinter damage to the plot stakes and access tube covers, apparently by the native fauna, was disruptive to monitoring operations, however it has not affected the quality of the data.

Soil moisture data collected from the neutron probe is presented in Table 1. It should be noted that a refinement in the calibration of the neutron probe is underway and this may produce a slight change in the moisture contents. Operating costs were estimated by the producer and presented in Table 2.

Table 1. Soil moisture levels (cm/m) for each treatment (average of four replicates)

DEPTH(cm)	SOIL MOISTURE (cm/m) RIPPED & POCKETED SEP 90	JAN 91	RIPPED SEP 90	JAN 91	CONTROL SEP 90	JAN 91
25	16.4	23.3	16.3	21.2	18.0	20.9
50	17.4	19.4	20.6	22.2	17.8	17.8
75	18.6	21.0	23.2	23.0	17.4	18.3
100	25.1	25.4	25.8	27.8	20.8	21.0
125	30.0	32.4	30.9	31.4	23.9	25.9
Average Gain	2.8 cm/m		1.8 cm/m		1.2 cm/m	

Table 2. Operating costs for the Dammer-diker to treat eight of twelve plots with a total area of 2.4 ha.

	COST/HOUR	TOTAL COST	COST/HECTARE
Equipment	$3.00	$18.00	$7.50
Labor	6.00	36.00	15.00
Total			$22.50

CONCLUSIONS

Although no conclusions can be drawn from the study at this stage, there is an indication that the Dammer-Diker is showing some effectiveness at increasing the amount of soil moisture.

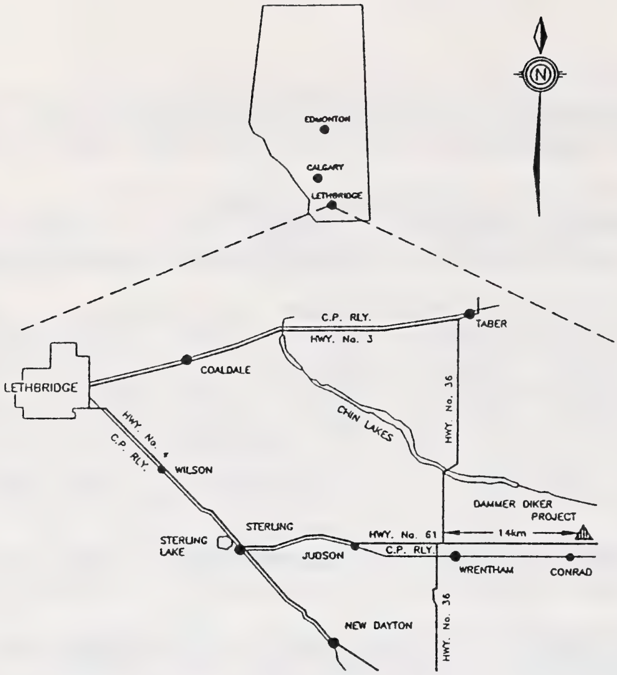

Figure 1. Location of the dammer-diker study project.

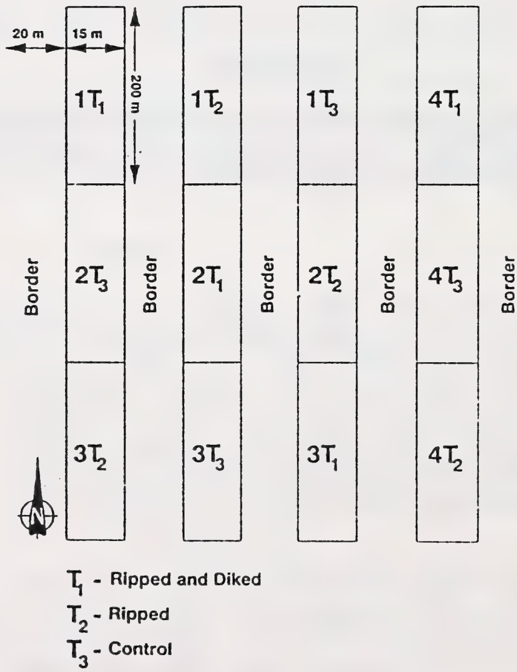

Figure 2. Plot layout for the dammer-diker study project.

RAINFALL SIMULATOR STUDIES OF SOIL EROSION

S.C. Nolan and T.W. Goddard[1]

INTRODUCTION

There is a lack of data and understanding of the extent and magnitude of soil erosion by water on the Canadian prairies (Coote, 1983; de Jong, 1988; Toogood, 1989). Field studies are needed to characterize erosion processes, as well as the effects of management practices to control erosion and help sustain agricultural productivity. Once these processes are characterized they can be used to develop quantitative models of soil erosion, which can provide tools for evaluating the effects of conservation management practices. It is not clear how well existing soil erosion models, such as the Universal Soil Loss Equation (Wischmeier and Smith, 1978) are adapted to Alberta conditions (Tajek et al., 1985). Seasonal variations in soil erodibility are also not well understood.

To assess the effects of water erosion and the validity of water erosion models in Alberta, there is a need to evaluate regional and seasonal variations of soil erosion in representative soil and cropping conditions. The objectives of this paper are to: i) Outline plans for a study to evaluate: A) the relative erodibilities of some representative Alberta soils, B) the effects of types and amounts of residue covers common in Alberta on soil loss, and ii) Present preliminary findings of a study using the methods described.

METHODOLOGY

The Guelph Rainfall Simulator (GRS II) based design was developed to obtain site specific measurements of soil erosion in field conditions (Tossell et al., 1987). Water is delivered under pressure to a static, solid cone pattern nozzle at 0.8 - 1.2 m heights, centered over a 1.0 m^2 study area. Simulator intensities can be varied with nozzle size, height and water pressure (ibid.) and were chosen using rainfall Intensity-Duration Frequency (IDF) curves from local climate stations (Atmospheric Environment Service, 1986). IDF curves are also usefull in relating simulation durations and corresponding measurements to probabilities of major rainfall events. For the simulation study described later, an intensity of 60 mm/hr (2.4 in/hr) for 20 minutes was chosen, which approximates a 1 in 25 year storm.

Runoff from the microplot is contained by borders, flows into an attached collection trough, and is drawn by vacuum into sample bottles. Subsamples may be drawn off at various time intervals via a T- valve. Erosion processes, including changes in rates of runoff and sediment loss are measured gravimetrically from samples collected from the contained plot area. Time to ponding and time to runoff are recorded so that depressional storage and infiltration rates can be inferred from differences between amounts of water applied and amounts of runoff. Site soil variables such as permeability (including depth to frozen layer), and soil and air temperatures are characterized. Surface roughness is also measured and used to calculate a roughness index (Romkens and Wang, 1986).

The following studies are planned to help characterize some erosion processes in Alberta:

A) Soil erodibility - Relative differences in soil erosion from representative Alberta soils (sand, loam, and clay loam textures) will be measured in fallow conditions, on constant slopes. These sites will

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also be used to measure seasonal variations in frozen, partially thawed and fully thawed soil conditions. Differences in soil losses due to varying organic matter levels (< 4 %, 4-8 % and > 8 %) will be measured from soils in fallow conditions with similar textures and slopes.

B) Effects of residue cover - The effects of residue type and cover (including canola) on soil movement will be evaluated where soil types are similar and representative of major soil textural groups. The effects of different levels of residue cover within a single management treatment will be measured, to attempt to isolate the effect of residue cover only.
The data will then be used to evaluate the validity of existing soil erosion models by comparing observed erodibility values to those predicted using the model.

PRELIMINARY FINDINGS

An initial study to evaluate the effects of conservation management practices on soil erosion using the rainfall simulator was carried out in November, 1990. Although conclusions may not be drawn from this unreplicated data, the following preliminary findings are presented to illustrate the types of information which can be obtained using a rainfall simulator.

A study site was located south of Calgary, on a clay loam soil (Dark Brown, 5.4 % organic matter, 3-4 % slopes). It had a fallow, a stubble (63 % wheat residue) and a no-till (85 % wheat residue) treatment. Figure 1 illustrates the dynamics of soil loss rates with time from each of the treatments. The soil loss from the fallow was much greater than that from the stubble or the no-till. Note that runoff start times varied.

The simulator data can be related to return periods of extreme rainfall events through the IDF curves discussed earlier. The abcissa of Figure 1 is also labelled with the return periods of rainfall events corresponding to the simulated rainfall. This information can be used to indicate the probability of soil erosion under various storm conditions. For example, it appears that at least a 1 in 2 year storm is required to initiate runoff from the no-till treatment. For planning purposes, this information could be used to indicate which management practices are required to reduce soil losses to tolerable levels during a 1 in 10 year storm.

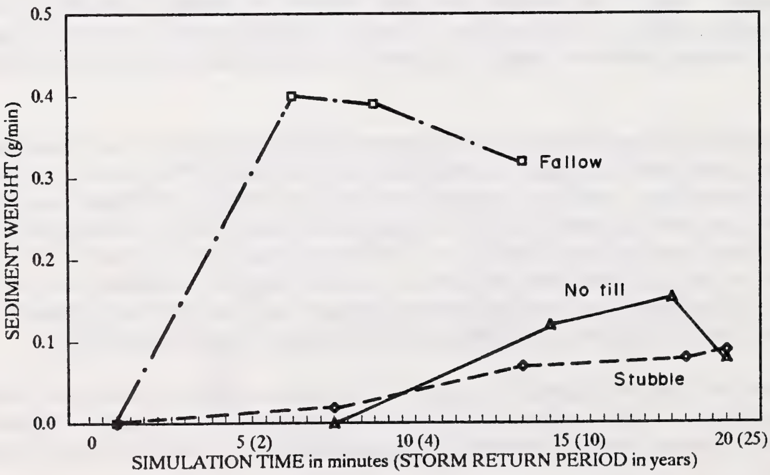

Fig. 1. Changes in rates of sediment loss with tillage treatment on a Dark Brown (clay loam).

SUMMARY

The rainfall simulator (GRS II) allows measurement of many important erosion processes in field conditions. Measurements will help to characterize erosion by water in Alberta, including seasonal, organic matter, crop cover, management and other site specific variations. There is potential for quantitatively evaluating the effects of conservation management practices on soil erosion, adding a useful dimension to sustainable agricultural research.

ACKNOWLEDGEMENTS

This study has been funded in part by the Canada Alberta Soil Conservation Initiative (CASCI). The following people have been very helpful in setting up and carrying out the study: Germar Lohstraeter, Dan Heaney, Murray Green, Wayne Wilderman, Gordon Dunn, John Bell, and Brad Lowrie.

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FIELD EVALUATION OF A CORNER PIVOT EQUIPPED WITH NELSON(TM) ROTATOR SPRINKLER HEADS

GORDON S. COOK P.ENG. [1]

INTRODUCTION

The introduction of a new type of sprinkler head called the Nelson R30 Series Rotator(TM) by Nelson Irrigation Corporation of Walla Walla, Washington sparked a great deal of interest within the irrigation community in southern Alberta during the spring of 1989. The Rotator(TM) sprinkler head has several features which make it ideal for many southern Alberta pivot irrigation applications. Firstly, it is well suited for low pressure applications where impact sprinklers would perform poorly, (140 to 210 kpa - 20 to 30 psi), yet is also adaptable to normal medium pressure impact sprinkler applications (210 to 345 kpa - 30 to 50 psi). Secondly, the Rotator(TM) can be mounted on drop tubes to help combat wind drift, but maintains a diameter of throw approximately 50% greater than spray heads operating at similar pressures and heights. Thirdly, the Rotator(TM) sprinkler head can be used in conjunction with flow control nozzles or pressure regulators. The three features outlined above make the Rotator(TM) sprinkler head especially suited to low pressure and/or drop tube applications where the soil intake rates are too low or the terrain is too severe for standard spray head application rates. (The use of brand names is solely for the benefit of the understanding of the reader and is in no way an endorsement for a particular product by the author.)

Since no work had been done in evaluating the performance of a pivot using these new Rotator(TM) sprinkler heads in southern Alberta, staff at Alberta Agriculture's Irrigation Branch district office in Taber carried out several catch can tests under field conditions near Chin, Alberta during the months of June and July, 1989. The pivot was a new Reinke Electrogator 65G(TM) (8 towers with a swing arm corner system) outfitted with R30 Series Rotators(TM) using Nelson FCN(TM) nozzles and mounted on drop tubes at approximately 2 meters operating height. The system, owned by Perry Produce, was situated on the E 1/2 of 30-9-18-4. This parcel was virtually flat and had excellent access for catch can layout and measurement.

PROCEDURE

All test procedures were carried out according to ASAE Standard #S436 -<u>Test Procedure For Determining The Uniformity Of Water Distribution of Center Pivot, Corner Pivot, and Moving Lateral Irrigation Machines Equipped With Spray Or Sprinkler Nozzles</u>. Catch cans of one hundred millimeters diameter were laid out at 4.5 meter spacing along four rows radiating out from the pivot point. The cans were supported approximately 0.75 meters above the ground on stakes to eliminate the possibility of any crop inter-

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[1] Irrigation Specialist, Irrigation Development Section, Irrigation Branch, Taber.

ference. Each can row was placed under the outer 80% of the pivot length. Two rows running north from the pivot point continued out under the corner arm, but did not extend under the coverage of the end gun. Two rows running east from the pivot point stopped at the hinge tower. Each pair of catch can rows were spaced five degrees apart. In this way data was obtained with the corner arm fully extended as well as fully retracted.

Can catch volumes were measured using a graduated cylinder. Every effort was made to measure the catch volumes as soon as possible following a test run to limit potential evaporation. General weather conditions were recorded as best estimates for the actual time of the test.

Pivot speed tests were carried out on selected runs. Pivot speed was determined by placing a stake in line with the last tower, allowing the pivot to travel and recording the time and distance travelled along the wheel track. The pivot's percent timer setting and corresponding rotation time were also recorded. Catch can tests were carried out at two pivot speed settings, 36% and 27%. (Approximately 18 mm and 25 mm application depth respectively.)

Flow tests using a Collins flow meter were conducted to determine the flow through the pivot with the corner arm extended and retracted. Corresponding pivot operating pressures were recorded. Nozzle outputs at various locations along the pivot were checked to ensure actual nozzle output corresponded to predicted nozzle outputs on the manufacturer's sprinkler package printout.

The coefficient of uniformity (CU) was calculated using the Heermann and Hein modified equation as outlined in ASAE S436.

Distribution uniformity (DU) and potential application efficiency (PELQ) were calculated as outlined by Keller et al. (1978)

RESULTS

An overall average CU of 85.6 was obtained from 28 individual calculations. The values of CU ranged from a high of 92.7 to a low of 78.4. An average CU of 87.3 was obtained from the 15 runs with the system fully extended (odd numbered runs). The average CU for the 13 runs with the system retracted (even numbered runs) was 83.6.

An overall average DU of 78.9% was also obtained from the 28 individual runs. The values of DU ranged from a high of 87.9% to a low of 67.3%. An average DU of 81.0% was obtained for the fully extended tests while a DU of 76.5% was obtained for the tests with the corner arm fully retracted.

An average PELQ of 77% was obtained from 27 usable runs. Run 15B had a PELQ greater than 100% and was omitted. PELQ values ranged from a high of 99% to a low of 50%.

In order to determine an overall or season long CU and DU, the raw unweighted catch volumes for each can location were added together to obtain a cumulative catch from multiple irrigations. These cumulative catches were then used to determine a CU and DU for both the extended and retracted catch rows. Using these cumulative values, a CU of 94.7 and a DU of 96.5% were determined for runs with the system extended. A CU of 87.9 and a DU of 91.2% were determined for the runs with the corner system retracted.

Testing was carried out with the intent of causing a minimum of disruption to the landowner's farming operations and irrigation scheduling. Therefore, the test results reflect representative southern Alberta irrigating conditions on a season long basis. Considering the high winds which can be prevalent during the irrigation season, wind speeds occurring during all of the tests were relatively low.

Flow tests showed the actual flow of the system very near to the expected flow shown on the manufacturer's nozzle package printout for the corner arm extended. The design flow of 72.2 l/s (1144 US gpm) is 3.5% higher than the actual measured flow of 69.7 l/s (1105 US gpm). This was in spite of the fact that the actual pivot operating pressure was 14% lower than the design pressure for the sprinkler package. This pressure difference had little effect because the system was outfitted with flow control nozzles. These nozzles are used on all corner arm systems produced by the manufacturer in order to counteract the pressure variations caused by the change in flow due to the corner arm turning on and off. Design flow for the pivot with the corner arm retracted is 41.1 l/s (652 US gpm) (accumulated flow to tower number 8). However, even with the corner arm fully retracted, three sprinklers located on the corner arm continued to operate. This would add approximately 1.9 l/s (30 US gpm) of flow to the retracted system for a total flow of approximately 43 l/s (680 US gpm). Actual pump tests showed a retracted flow of 47.3 l/s (750 US gpm), 10% higher than design flow. In this case, the pivot point pressure was 24% higher than design pressure. This greater deviation from design parameters for the system retracted as compared to the system extended may be the cause for a lower average CU (83.6) and DU (76.5%) for tests with the system retracted as compared to the average CU (87.3) and DU (81.0%) with the system extended. This may also hold true for the lower CU and DU values based on the cumulative catches.

CONCLUSIONS

An overall average CU of 85.6 was lower than expected considering that the equipment was new, operating on flat ground, and using flow control nozzles. A higher CU value could have been expected if the sprinkler package had been operating at the design pressure, as opposed to the actual operating pressures experienced during the tests. However, the CU value is encouraging considering the various wind and weather conditions under which the testing was carried out.

The average PELQ of 77% is less than the design parameter of 80% often used in practice in southern Alberta. Considering the optimum field and equipment conditions, as well as the relatively good operating conditions under which the tests were carried out, a higher value had been hoped for. However, season long PELQ values of 75% may be a more realistic value for southern Alberta.

When the CU and DU were calculated from the cumulative raw catch volume data, higher values were obtained for runs with the system fully extended than with the system retracted. This would indicate that although the flow control nozzles limit the magnitude of the variation from design flow, the fact that the pivot operating pressure is above the sprinkler package design pressure still may cause some uniformity problems. However, the greatest contributing factor for the lower cumulatve CU and DU with the

corner arm retracted appears to be the apparent over irrigation by the retracted corner arm.

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MAPPING SALINITY TO MEASURE POTENTIAL YIELD OF WHEAT

R. C. McKenzie, D. R. Bennett, and K. M. Riddell

Information collected by datalogging with an EM38 was used to generate maps depicting the level and spatial distribution of salinity. The relationship between the level of salinity and wheat yield was used to predict the amount of wheat that could be produced within a specific delineation. This automated EM38 mapping system allows detailed mapping of salinity (50 observations/ha) at a lower cost than conventional techniques. This system provides a means of improving current estimates of the extent of land affected by salinity, the rate at which salinity is expanding or declining and the resultant depression or improvement in crop yield.

Soil salinity is an important and spatially variable factor that limits the production of crops on many western Canadian soils. Reports are conflicting as to how much land is affected by salinity in Alberta and Saskatchewan. Anderson and Knapik (1984) report estimates for salinity in Alberta ranging from 0.25 million ha (Alberta Agriculture 1979) to 1.5 million ha (Sommerfeldt 1984). This situation has developed because published estimates are based on insufficient data due to the high costs for labour and laboratory analyses associated with traditional salinity mapping. Anderson and Knapik (1984) report various estimates of the annual rate of increase of soil salinity that range from 10-16% by McCracken (1974), 10% by Vander Pluym (1981) to 0.8% by Anderson and Knapik (1984). This lack of consensus has developed because of the deficiency in detailed measurements on seasonal and annual variation in the extent of salinity in saline seeps. These variations are caused by changes in climate or groundwater movement.

The EM38 electromagnetic induction meter, which does not require direct soil contact, permits a large number of salinity measurements to be obtained at a lower cost than conventional salinity mapping techniques. Temperature, moisture, and texture corrections have been used to convert EM38 readings to saturated paste extract equivalents (McKenzie et al. 1989). Datalogging equipment and computer drafting technology have also been developed to allow the preparation of salinity maps on the basis of detailed EM38 surveys (McKenzie et al. 1987).

Information on the tolerance of crops to salinity show a large divergence on how much reduction in growth occurs at a particular level of salinity. Published and unpublished levels of tolerance of wheat to salinity (Table 1) indicate a 50% yield at an EC of from 6.5 (Ballantyne 1962) to 19.1 and 25.3 (Francois et al. 1986). These discrepancies in tolerance occur because of differences in the stages of growth at which plants were subjected to salinity stresses, and to differences in types of salts present in saline soils. Field experiments, where salinity stresses are often combined with moisture stresses, differ from controlled experiments because frequent water applications on controlled experiments minimize salinity stresses or move salts out of the root zone of seedlings which are in their most salt-sensitive stage.

Table 1. Tolerance of wheat to salinity

	EC at which 50% yield occurs
Maas and Hoffman (1977)	13.0
Fowler and Hamm (1980) Black Chernozems in Saskatchewan	8.8
Ballantyle (1962) Brown Chernozems in Saskatchewan	6.5
McKenzie and Chomistek (Alberta data unpublished)	
Dryland hard wheat (0.0-0.30 m)	7.6
Irrigated soft wheat (0.0-0.30 m)	6.6
Irrigated soft wheat (0.0-0.6 m)	8.5
Francois Maas Donovan and Youngs (1986) California	
bread wheat	19.1
durum wheat	25.3

The relationship between the yield of irrigated soft wheat and dryland hard wheat and soil salinity as measured by several methods has been determined by McKenzie and Chomistek (1990) based on three years of field sampling. The choice of methods did not appreciably alter the correlation between yield of wheat and soil salinity (Fig. 1). If the purpose of mapping salinity is to make a reliable estimate of crop growth at the least cost, then the EM38 with a datalogger should provide the best result.

The purpose of this study was to compile salinity information using an automated EM38 mapping system to generate maps illustrating the magnitude and spatial distribution of soil salinity. Predictions of the potential yield of wheat within specific delineations were then developed from known relationships between the level of salinity and wheat yield.

Methods

The Land Evaluation and Reclamation Branch of Alberta Agriculture has commenced mapping salinity with an EM38 and datalogger on blocks of land ranging in size from 16-32 ha. which were affected by canal seepage. These maps were used to estimate the loss of yield of soft wheat which could be attributed to soil salinity. Projected yields were based on a yield response curve developed by McKenzie and Chomistek 1990 (Fig. 2). With this procedure, data was collected which would provide a means of estimating the benefits that could be obtained from reclamation.

The mobile automated EM38 mapping system was used to conduct spring and fall salinity surveys on parcels affected by canal seepage. Salinity mapping was conducted on a 10 x 20 m grid using an all terrain vehicle to pull an EM38 meter on a nonmetallic cart. Operating speed was limited to 7 km/h. A magnetic switch, located on a bicycle tire attached to the ATV, triggered the EM38 to take readings at 10-m intervals. Transects were spaced 20 m apart and were run at right angles to the direction of the canal in order

to detect changes in salinity with distance from the canal. The grid was traversed twice to accommodate the EM38 meter in both the horizontal and vertical modes.

Grid locations and corresponding readings from the EM38 meter were recorded on a portable computer (Tandy 102) attached to the ATV. A survey of 32 ha required enough memory capacity to store grid locations and readings for approximately 1000 horizontal and 1000 vertical sites. After field collection, the data was transferred to a personal computer for contouring. The contouring package can use either the inverse squared or kriging statistical methods to interpolate between points.

The time and manpower to survey a 32-ha parcel of land using a 10 x 20 m grid was about 1.5 man days. Two people were required for one-half day to survey and stake the grid and one person was required for one-half day to collect the EM38 data.

Predicted yields for zones of salinity (i.e. EC ranging from 4 to 5 dS/m) on each salinity map were calculated using a yield response curve (Figure 2). The area within each zone of salinity was calculated by the contour mapping program.

Soil samples were taken in 30 cm increments to a depth of 1.2 m at random locations throughout the grid to check the accuracy of EM38 derived salinity values. Samples were analyzed for saturated paste electrical conductivity. Average profile salinity readings for each sampling location were determined using depth contribution factors from Wallenhaupt et al. (1986).

Results and Discussion

Contour maps of soil salinity were produced from EM38 data collected in the spring at sites in the Lethbridge Northern Irrigation District (LNID) Fig. 3 and Bow River Irrigation District (BRID) Fig. 4. These maps illustrate the spatial variability and extent of the areas affected by salinity. Acreage estimates for specified levels of salinity (i.e. 1-2 dS/m) derived from these maps were then multiplied by the relative yield values for these levels of salinity to obtain an estimate of the relative yield of irrigated wheat (Table 2). The LNID and BRID sites were estimated to have the capability of producing 83.9 and 90.8% respectively of normal yield. These estimates are based on average response to salinity. Yields can be appreciably higher or lower than average depending upon whether early season rainfall or irrigations reduce surface salinity or reduce salt induced moisture stresses. EM38 derived salinity values were similar to average profile salinity readings determined using saturated paste extract electrical conductivity values.

This technique offers a method of mapping large areas to determine amount and severity of soil salinity. The mapping can be repeated to measure changes in amount of soil salinity, for economic studies on the potential or actual benefits from soil reclamation measures.

Fig. 1

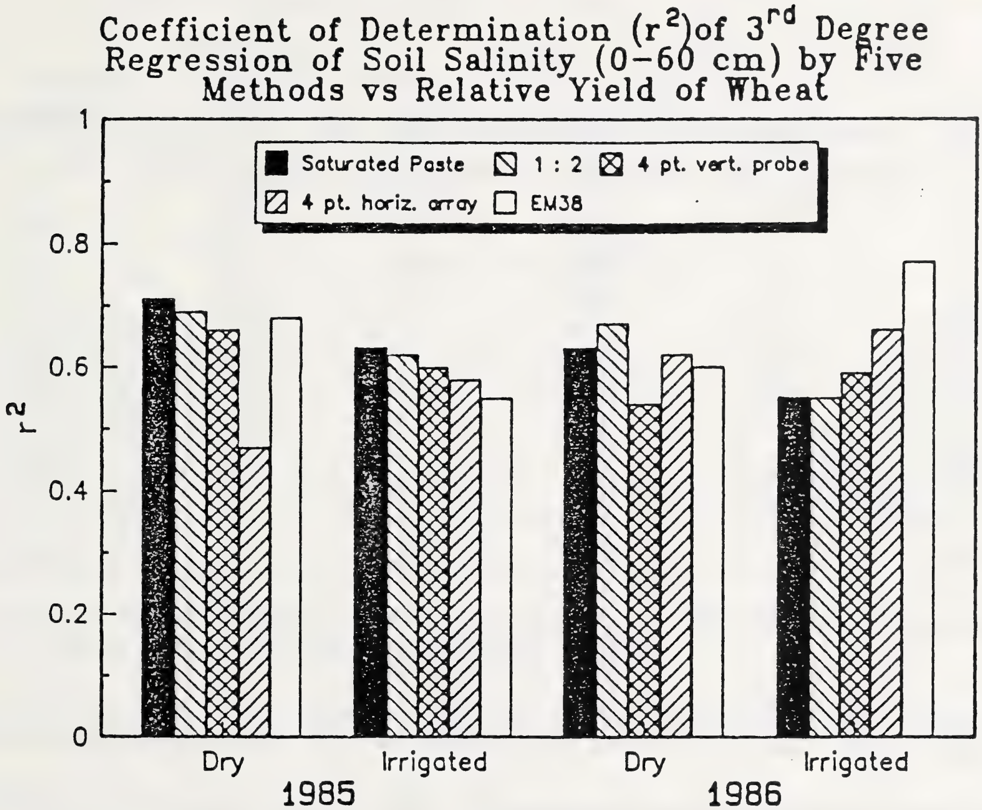

Fig. 2 Relative yield of irrigated soft wheat compared to soil salinity for 0-50 cm.

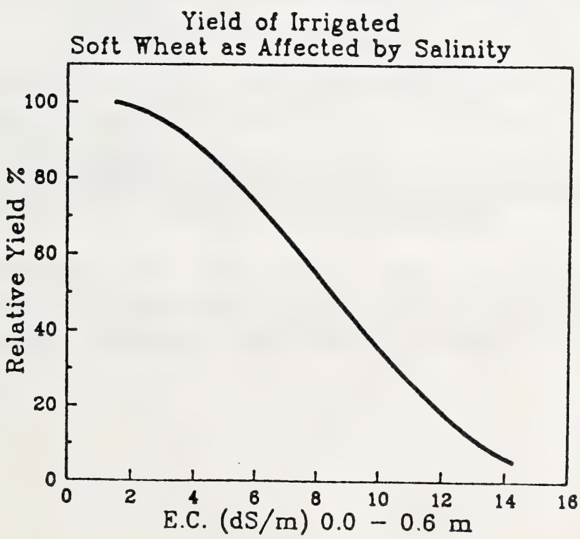

Fig. 3 Salinity map derived from spring horizontal EM38 readings at a site in the LNID.

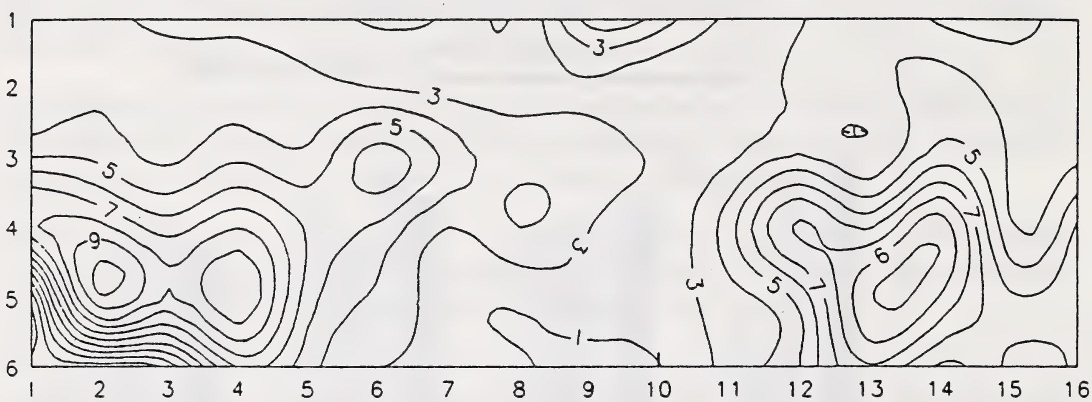

Fig. 4 Salinity map derived from spring hotizontal EM38 readings at a site in the BRID.

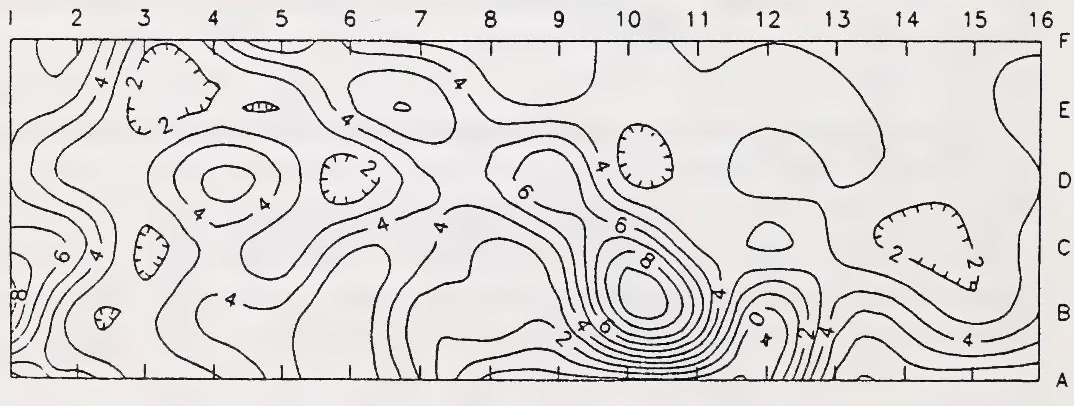

Table 2. Area of salinity and relative yield of wheat determined from EM38 salinity mapping at two sites.

EC dS/m 0-60 cm	% relative yield of wheat	LNID		BRID	
		% of area	Area x relative yield	% of area	Area x relative yield
1-2	100	2.4	2.4	0.1	0.1
2-3	97.3	22.4	21.8	25.8	25.1
3-4	92.5	32.5	30.1	44.5	41.2
4-5	86.5	12.2	10.6	19.0	16.4
5-6	78.2	8.5	6.6	6.9	5.4
6-7	69.3	7.7	5.3	3.5	2.4
7-8	59.9	5.3	3.2	0.3	0.2
8-9	50.1	4.7	2.4		
9-10	40.0	3.3	1.3		
10-11	31.0	0.8	0.2		
Total			83.9		90.8

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UPPER AND LOWER ACCEPTANCE LIMITS ESTABLISHED FROM EXISTING SOIL ANALYSIS

K. Au[1], P.G. Karkanis[1] and G.B. Schaalje[2]

INTRODUCTION

A large number of soil samples are analyzed each year for the Soil and Water Laboratory, Alberta Agriculture, through contracts with private laboratories. Some 13 298 soil analyses were completed by two different private laboratories in the fiscal year 1988-89, 10% of which were also analyzed by the Soil and Water Laboratory of Alberta Agriculture as quality control samples.

Analysis results are received from private laboratories electronically and are assessed for accuracy according to arbitrary acceptable limits specified in the contracts, but this always raises the question of " Which lab result is right ? ". Due to the importance of these limits in determining the accuracy of the analysis results, an attempt was made to statistically determine the upper and lower acceptance limits for each analysis parameter.

MATERIALS AND METHODS

Analysis results from 1 003 soil samples from the Brown and Dark Brown soil zones in Southern Alberta were examined. These analyses included saturation percentage, pH, electrical conductivity (ECe), soluble calcium and magnesium, soluble sodium and soluble potassium. The analysis results were obtained from two different private laboratories and each test was repeated in the Soil and Water Laboratory of Alberta Agriculture. Due to the unequal number of samples from each private laboratory, the calculations were simplified by combining the results from the two private laboratories together and referring to this as the "Private Laboratory".

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The variance of the analysis data were determined for each parameter from both Private and Soil and Water Laboratories. Sample measurements obtained from both laboratories were assumed to follow the statistical model:

$$y1_i = \mu_i + e1_i \quad \text{------------------------------------} \quad (1)$$
$$y2_i = \mu_i + e2_i \quad \text{------------------------------------} \quad (2)$$

where $y1_i$ = Soil and Water Lab. measurement for soil sample i
$y2_i$ = Private Lab. measurement for soil sample i
μ_i = theoretically true measurement (unknown)
$e1_i$ = measurement error of Soil and Water Lab with variance σ_1^2
$e2_i$ = measurement error of private lab with variance σ_2^2

In order for σ_1^2 and σ_2^2 to be constant for all values of μ_i, some parameters were analyzed on the arithmetic scale and some on the logarithmic scale. For examples soluble calcium and magnesium, and soluble sodium data were separated into two ranges within which σ_1^2 and σ_2^2 were constant.

The difference between the two measurements were thus equal to the difference between the two measuremental errors.

$$y1 - y2 = e1 - e2 \quad \text{-----------------------------} \quad (3)$$

A preliminary analysis indicated that the variances of the two errors (σ_1^2 and σ_2^2) were approximately equal. Assuming a common error variance of σ^2 for each laboratory determination, the variance of (e1 - e2) is $2\sigma^2$.

By using a one-way analysis of variance procedure with "sample" as factor, the error Mean Square within the sample estimates is σ^2. The upper and lower 95% confidence limits for y1-y2 were thus computed as follows:

$$(-Z^{.95}\sqrt{2}\sigma \leq y1 - y2 \leq Z^{.95}\sqrt{2}\sigma) \quad \text{-------------------} \quad (4)$$

$Z^{.95}$ - Z value at 0.05 level

Rearranging equation (4), we get

$$L = y1 - Z^{.95}\sqrt{2}\sigma$$
$$\text{and} \quad U = y1 + Z^{.95}\sqrt{2}\sigma \quad \text{-----------------------------} \quad (5)$$

as limits beyond which y2 should rarely occur by chance given by y. For data analysed on the logarithmic scale with y = log (V), the corresponding limits are

$$L = V1 \,/\, \exp\,(Z^{.95}\sqrt{2}\sigma)$$

$$\text{and } U = V1 \times \exp\,(Z^{.95}\sqrt{2}\sigma) \qquad \text{------------------} \quad (6)$$

Scattergrams of all parameters were plotted using Soil & Water Lab data on the x-axis and the Private Lab data on the y-axis. Acceptance regions computed using equation (4) were also plotted.

RESULTS AND DISCUSSIONS

The means, variances and correlations of analyses data obtained from the Private Laboratory and the Soil and Water Laboratory and the error mean square (σ^2) within samples are presented in Table 1.

The relationships for saturation percentage and pH (Fig.1) showed additive differences (fixed amount differences) between laboratories, whereas ECe and potassium (Fig.2) showed multiplicative differences (fixed percentage differences). Parameters having additive differences were analysed on the arithmetic scale, while those showing multiplicative differences were analysed on the logarithmic scale. Calcium and magnesium, and sodium exhibited a mixture of additive and multiplicative differences (Fig.3). An additive difference was observed for calcium and magnesium in the range 1.0 to 11.0 meq/L, whereas a multiplicative difference was detected over the range 11.0 to 120.0 meq/L. Sodium has an additive difference from 1.0 to 5.0 meq/L and a multiplicative difference from 5.0 to 180 meq/L.

Table 2 gives 95% upper and lower acceptance limits as determined by Equations (5) and (6).

RECOMMENDATION

The statistical results shown in this study indicate that in a given measurement of any laboratory, ninety-five (95) times out of one hundred (100) will fall between the upper and lower limit.

It is our recommendation that the upper and lower acceptance limits depicted in Table 2, be implemented in future "Agreement for laboratory services for standard soil chemical analysis."

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Table 1. Mean values of analyses results from private laboratories and Soil and Water Laboratory and the analyses of variance.

analyses parameters	range		measurement within Soil and Water Lab mean	variance	measurement within Private Lab mean	variance	correlation	error mean squre within samples
% sat	20-120		52.79	173.50	52.90	182.00	0.96	5.2920
pH	4.5-8.5		7.60	0.38	7.55	0.35	0.93	0.0220
ECe	0.14-19.0	mS/cm	4.07	19.36	4.01	18.74	1.00	0.0008 *
Ca & Mg	1.0-120.0	meq/L	27.75	844.20	27.31	821.10	1.00	3.4360 *
	1.0-11.0	meq/L	5.34	5.46	5.25	5.98	0.92	0.3102
	>11.0-120	meq/L	50.48	668.70	49.68	653.10	0.99	0.0009 *
Na	1.0-180	meq/L	26.50	1522.00	26.42	1504.00	1.00	4.3790 *
	1.0-5.0	meq/L	1.45	1.39	1.48	1.34	0.97	0.0370
	>5.0-180	meq/L	48.86	1820.00	48.69	1795.00	1.00	0.0006 *
K	.01-4.0	meq/L	0.55	0.41	0.53	0.40	0.99	0.0030 *

* - logarithmic transformation

Table 2. Upper and lower acceptance limits of various parameters computed from analysis results of 1003 soil samples.

analyses parameters	range		upper limits	lower limits
% sat	20-120		control value + 6	control value - 6
pH	4.5-8.5		control value + 0.4	control value - 0.4
ECe	0.14-19.0	mS/cm	control value x 1.082	control value / 1.082
Ca & Mg	1.0-120.0	meq/L		
	1.0-11.0	meq/L	control value + 1.54	control value - 1.54
	>11.0-120	meq/L	control value x 1.09	control value / 1.09
Na	1.0-180	meq/L		
	1.0-5.0	meq/L	control value + 0.54	control value - 0.54
	>5.0-180	meq/L	control value x 1.07	control value / 1.07
K	.01-4.0	meq/L	control value x 1.16	control value / 1.16

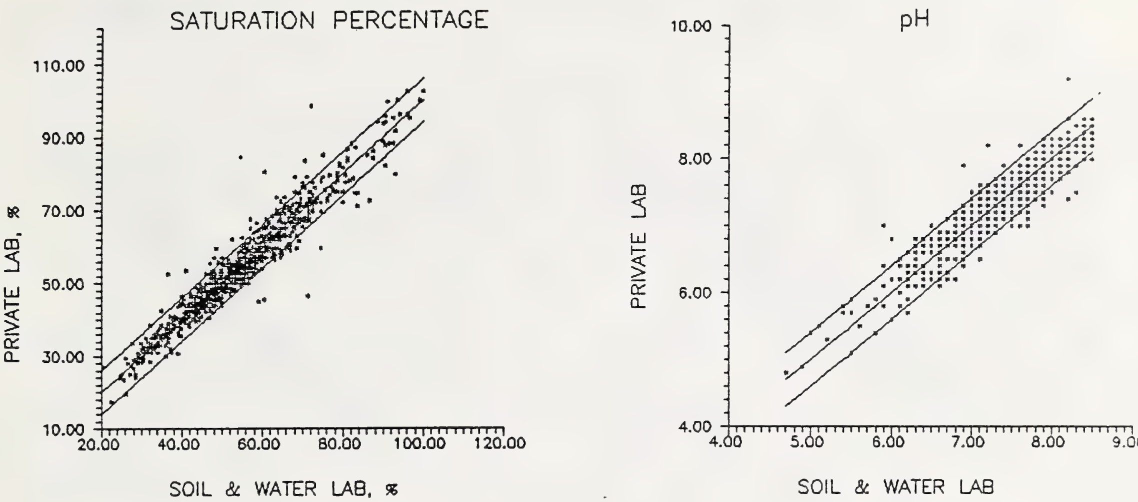

Fig. 1. Additive relationship between measurements for saturation percentage and pH.

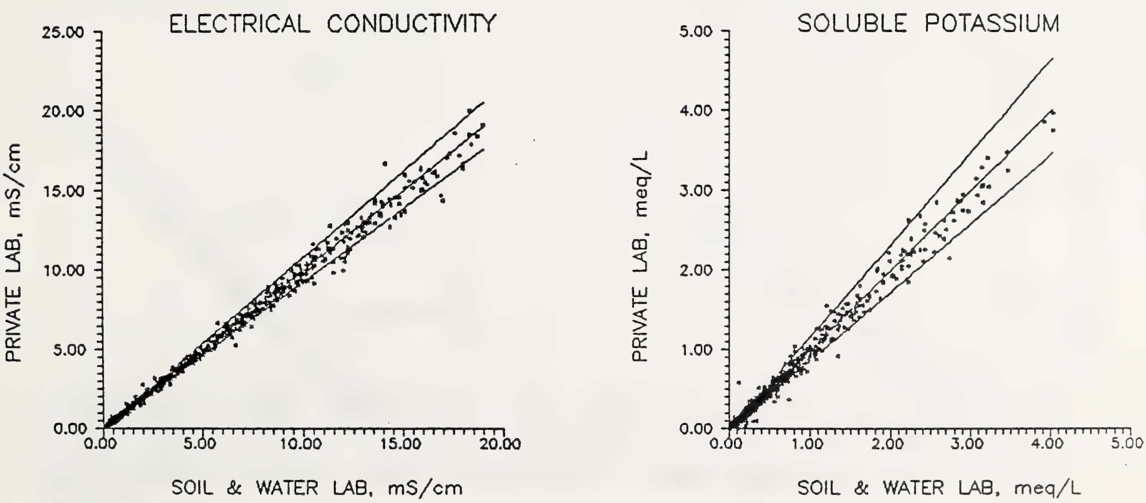

Fig. 2. Multiplicative relationship between measurements for electrical conductivity and soluble potassium.

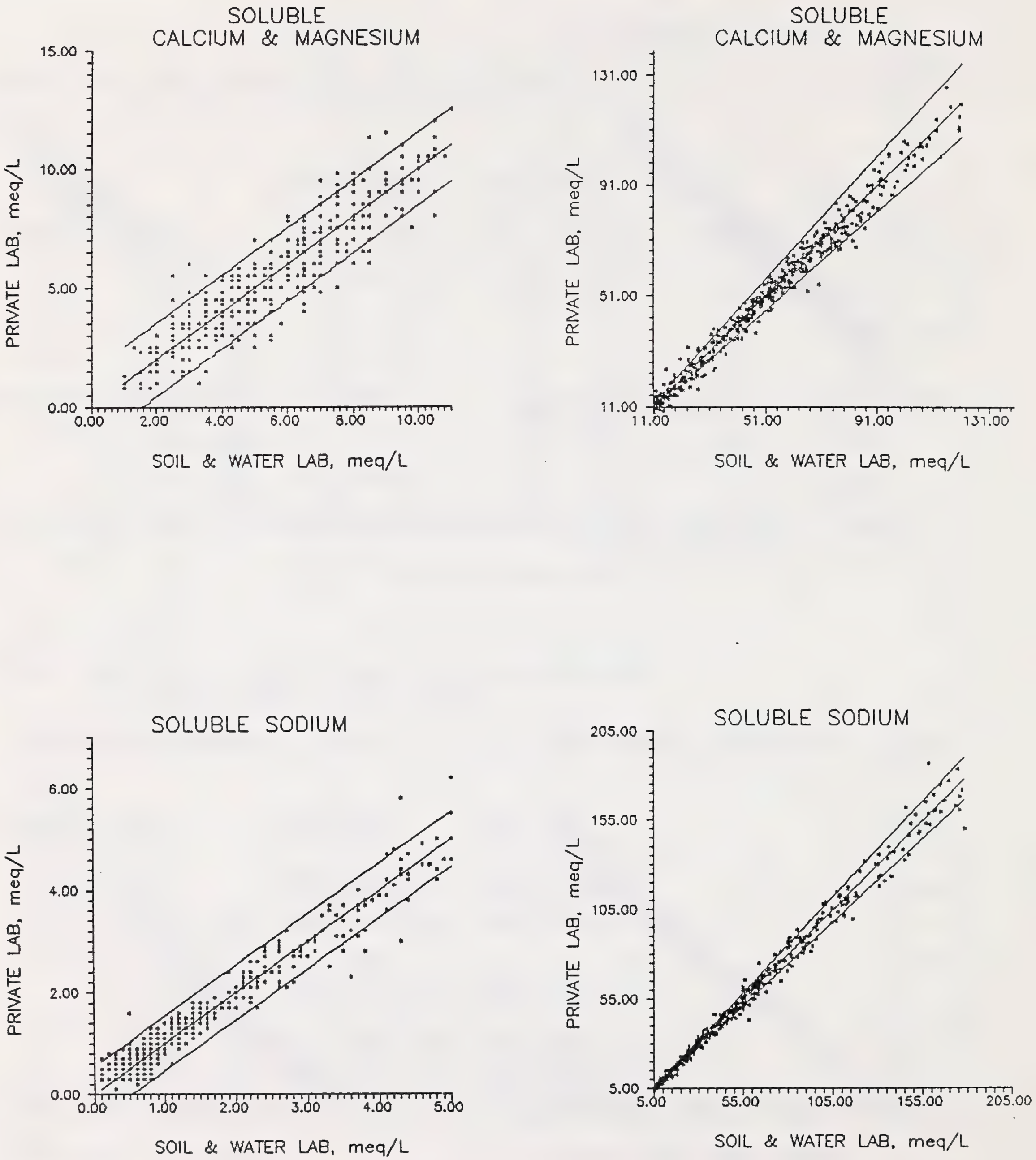

Fig. 3. Additive and multiplicative relationships between measurements for soluble calcium & magnesium and soluble sodium.

EM-38 CALIBRATION STUDY

K. M. Riddell[1]

INTRODUCTION

The use of electromagnetic induction techniques for mapping spatial and temporal changes in soil salinity is a key component of the ICW Reclamation Effectiveness program. The cart-mounted EM-38, connected to a microcomputer by an analog-digital converter, offers a rapid, automated method for cost-effective mapping of soil salinity. EM-38 salinity readings are converted to equivalent saturation paste electrical conductivities (ECe) using empirical equations developed by McKenzie et al. (1989) and Rhoades et al. (1990). The EM-38 is being increasingly used to map salinity but the empirical equations used to generate ECe values have not been widely tested. Knowledge of the accuracy of EM-38 generated salinity readings is essential in order to establish confidence in this technique. In response to this need, a field study was designed to compare the accuracy of the two empirical equations in predicting soil salinity as determined by conventional laboratory methods.

METHODS

A single transect, running perpendicular to an irrigation canal, was surveyed as part of an overall grid for an EM-38 soil salinity investigation (Figure 1). The transect was 262.5 m in length and had individual stations every 10.5 m. The spacing of 10.5 m was selected to accommodate 5 wheel rotations of the counter wheel (diameter=2.1 m) on the automated EM-38 mapping system.

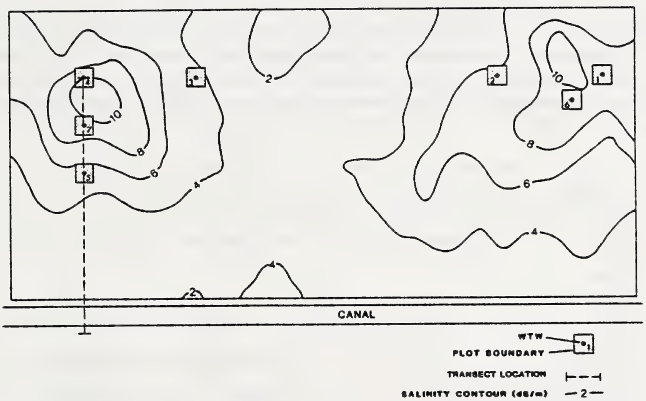

Figure 1. Location of EM-38 calibration transect of LNID ICW reclamation site.

Soils along the transect are a combination of Saline, Rego Dark Brown Chernozemic and Saline, Carbonated Humic Gleysolic developed on blanket deposits (1-2 m) of silty clay loam lacustrine material overlying clay loam till. Shallow water tables (1 - 2 m below ground surface) occur at a break-in-slope, approximately 100 m downslope from the toe of the canal.

Prior to starting, the EM-38 was zeroed and nulled in the vertical

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mode and soil temperatures were taken at the 30, 60 and 90 cm depths at upper-, mid- and lower-slope positions. Handheld EM-38 readings were then taken in the vertical mode at each station along the transect. The EM-38 was then mounted on a cart in the vertical mode and automated readings were taken at each station. Handheld readings allow the EM-38 instrument to be placed directly on ground surface, whereas automated readings are taken with the EM-38 in a cart approximately 4 - 5 cm above ground surface.

After the EM-38 measurements were taken, soil samples were collected from 0-15, 15-30, 30-60, 60-90, and 90-120 cm depth increments at each station. Soil samples were taken with a truck-mounted coring unit. Saturation paste extract electrical conductivities (Rhoades 1982) and gravimetric moisture contents (Gardner 1986) were determined on each soil sample according to standard methods. EM-38 measurements and soil samples were taken on April 25, 1990.

Handheld and automated EM-38 measurements were compared by graphing one variable against the other and calculating the least squares linear coefficient of determination (R^2). Temperature corrected, handheld and automated, EM-38 measurements were converted to equivalent ECe using empirical equations developed by McKenzie et al. (1989) and Rhoades (1990). Laboratory-determined ECe from individual sampling depths were converted to profile ECe's using depth contribution factors developed by Wollenhaupt et al. (1986). The predicted ECe derived from two different empirical equations, using handheld and automated EM-38 readings, were compared to each other and profile ECe determined in the laboratory by graphing and least squares linear coefficients of determination (r^2).

RESULTS AND DISCUSSION

Graphical comparison of handheld to automated EM-38 readings reveal an almost perfect 1:1 relationship (Figure 2). Automated readings were usually 1 - 2% higher than handheld readings despite the instrument being carried 4 - 5 cm above ground level. These results suggest there is no loss in instrument sensitivity associated with the cart assembly or motion related effects.

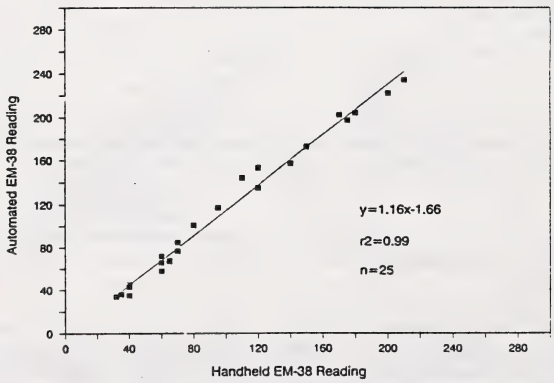

Figure 2. Handheld vs automated EM-38 readings with instrument in vertical orientation

Predicted ECe derived from empirical equations developed by Rhoades et al. (1990) and McKenzie et al. (1989) demonstrate a close relationship with laboratory-measured ECe (Figure 3). Linear coefficients of determination of 0.89 and 0.90 are excellent when considering the sampling volumes of EM-38 and soil sampling/laboratory methods are very different. The EM-38 detects soil salinity over the 1 m width between the transmitter and receiver coils, whereas soil samples detect salinity within a narrow

8 cm core tube. ECe estimated using the equation developed by Rhoades et al. (1990) were usually higher than the laboratory-measured ECe, whereas ECe estimated using the equation developed by MCKenzie et al. (1989) were consistently lower than laboratory-measured ECe.

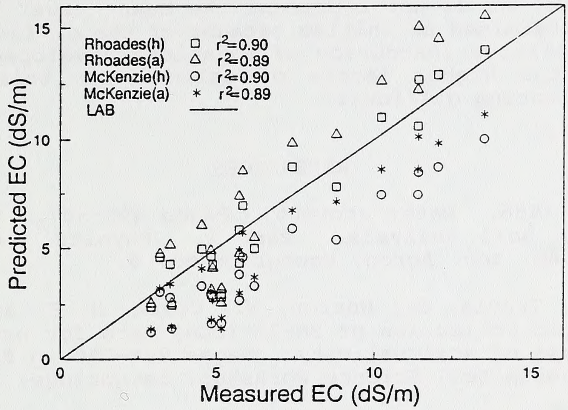

Figure 3. Predicted ECe, derived from Rhoades et al. (1990) and McKenzie et al. (1989), using handheld and automated EM-38 readings vs laboratory measured ECe.

The accuracy of salinity values predicted by using the EM-38 and empirical equations was assessed by splitting laboratory-determined salinities into four categories (0-4, 4-8, 8-12, and 12-16 dS/m) and then calculating the number of salinity values correctly identified by empirical techniques in each category. Results show equations developed by McKenzie et al. (1989) are accurate in the low range of salinity (0-4 dS/m) and equations developed by Rhoades et al. (1990) are accurate in the high range (12-16 dS/m) (Table 1).

Table 1. Percent of salinity values in specified categories (e.g. 0-4 dS/m) correctly predicted by different empirical equations using hand-held and automated EM-38 numbers.

	% Correctly Identified			
Salinity Category EC (dS/m)	McKenzie et. al (1989) Hand-held, Vertical	McKenzie et. al (1989) Automated, Vertical	Rhoades et. al (1990) Hand-held, Vertical	Rhoades et. al (1990) Automated, Vertical
0 - 4	100	100	50	50
4 - 8	18	36	73	73
8 - 12	25	75	50	25
12 - 16	0	0	100	100
Overall	33	52	67	62

Overall accuracies of 62 - 67% for equations developed by Rhoades et al. (1990) compare very favourably with results in the published literature (Rhoades et al. 1990). Once again, it must be stressed that laboratory determined salinities do not represent the best "true" value to compare against EM-38 determined salinities because of the difference in sampling volumes. The relative inaccuracy of equations developed by McKenzie et al. (1989) in the higher levels of salinity at this site may make reclamation monitoring difficult.

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